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SPECIAL STUDY S-52-3

HEAR (DOER) RIVER

ARTIFICIAL FLOODING

POTENTIALITIES

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PREPARED BY
MILITARY HYDROLOGY BLD BRANCH
ENGINEERING DIVISION
WASHINGTON DISTRICT, CORPS OF ENGINEERS
WASHINGTON, D. C.
NOVEMBER 1952

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RIVER (ROCK) RIVER

ARTIFICIAL FLOODING

POTENTIALITIES

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EXHIBITS

- A Description of Watercourse and Control Structures,
The Rur (Roer) and Urft Rivers
- B Abstracts of German Technical Literature on Rur Valley
Dams
- C Excerpts from "Engineer Operations by the (U. S.)
VII Corps in the European Theatre; Volume VI, The
Roer River Crossings and Advance to the Rhine."

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SPECIAL STUDY S-52-3

ARTIFICIAL FLOODING POTENTIALITIES
RUR (ROER) RIVER

SECTION I
INTRODUCTION

1-01 ASSIGNMENT.

This special study was assigned to the Military Hydrology Research and Development Branch, Engineering Division, Washington District by letter from Office, Chief of Engineers, ENGFE, to the Division Engineer, North Atlantic Division, subject "Military Hydrology R&D Project No. 8-72-12-001: Special Assignment" dated 9 September 1952.

1-02 PURPOSE AND SCOPE.

a. This report presents information regarding the hydraulic effects and nature of artificial flooding potentialities in the Rur (Roer) River basin. It consists largely of a compilation and consolidation of information presented in various intelligence documents and technical publications, with certain supplementary analyses and discussions. The material forming the basis of this report was limited to that available in the Washington, D. C. area. Additional data from other sources and field reconnaissance are needed to adequately cover the subject for general military requirements.

b. The report is designed to furnish basic data and results of analyses needed to answer questions concerning:

(1) Normal and extreme discharges, stages, and velocities at key stations on the Rur River in the reach influenced by the Urft Dam, Schwammenauel (Rur) Dam and other dams in the group commonly known as the "Schmidt Dams" or "Eifeltalsperren" (Eifel Reservoirs).

(2) Stream characteristics including gradients, depths and widths of channel and flood-plain in that reach.

(3) Data concerning locations and zero elevations of gaging stations.

(4) Data concerning locations and dimensions of dams and bridges.

(5) The extent of flooding possible by erection of temporary dams.

*German spelling is "Rur," Dutch spelling is "Roer."

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(6) The magnitude and duration of flood waves and flow variations created by breaching or regulated discharge from the dams and reservoirs and the effect on military bridging and crossing operations on the Rur River.

1-03 ARRANGEMENT.

This report is sub-divided as follows:

Section I	Introduction
Section II	Drainage Basin Characteristics and Developments
Section III	Hydrologic Characteristics
Section IV	Artificial Flood Potentialities
Section V	Effect on Military Operations
Bibliography	
Tables	
Plates	
Exhibit A	Description of Watercourse and Control Structures, The Rur (Roer) and Urft Rivers
Exhibit B	Abstracts from German Technical Literature
Exhibit C	Excerpts from VII Corps Report: "The Roer River Crossings and Advance to the Rhine."

1-04 DEFINITIONS AND REFERENCE DATUM.

a. Equivalent English-Metric Terms.

Both the English and Metric systems are used in this report. Conversion factors are presented for convenient reference in Table 1.

b. Hydrologic Terms and Abbreviations.

(1) The following abbreviations are used in this report:

cm	centimeters
mm	millimeters
m	meters
km	kilometers

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l	liters
km ²	square kilometers
m ³	cubic meters
m ³ /sec	cubic meters per second
fps	feet per second
m/sec	meters per second

(2) Abbreviations, in conformance with standard German Hydrologic practice, are defined in Table 2.

c. Elevation Datum.

All elevations referred to in this report are in meters above "Normal Null" (N. N.), the zero of the German Land Survey Datum.

d. Kilometerage Datum.

River kilometers in this report are based on Zero Kilometer at a point 1.1 km east of Monti Rigi, Belgium in the headwaters of the Rur River and are measured in a downstream direction.

e. Maps.

The area of the Rur River basin is covered by the following standard American-British maps of GSOS (Geographic Section General Staff) series:

<u>Scale</u>	<u>GSOS Map Series</u>	<u>Sheet Numbers</u>
1:250,000	4042	A, B, E
"	4356	K-51, K-52
1:100,000	4416	Q-1, R-1, S-1
"	4336	4, 9
"	2541	2, 6
1:25,000	4414	4802, 4902, 4903, 5003, 5004, 5104, 5204, 5304, 5404

f. Reference Grid.

Grid references cited in this report are to the "Nord de Guerre" Grid System.

1-05 REFERENCES.

All references cited in this report are listed in the Bibliography following Section V of the text.

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SECTION II
DRAINAGE BASIN CHARACTERISTICS AND DEVELOPMENTS

2-01 GENERAL.

a. The Rur (Roer) River rises in the Eifel Highlands in Belgium and flows generally northward along the German side of the Belgium-German and Dutch-German borders, emptying into the Maas (Meuse)* River near Roermond, Holland. It serves as a major source of domestic and industrial water supply for the Prussian Rhine Province and provides electric power for the area of Germany south and southwest of Cologne (Köln). The major tributaries of the Rur River are the Urft, Kall, Inde, and Wurm Rivers. Locations of the river and its tributaries are shown on the maps presented as Plates 1, 2, and 3 of the report. A detailed description is contained in Reference 1, a translation of which is included in this report as Exhibit A.

b. This report is confined to consideration of the main stem of the Rur River below the Urft and Schwammenauel (Rur) Dam.

2-02 TOPOGRAPHY.

The headwaters of the Rur River are in the Eifel Highlands which comprise three distinct regions; the "High Eifel," a region dissected by deeply incised streams; the "Volcanic Eifel," characterized by lava-blocked valleys and volcanic crater lakes; the "Hohe Venn," composed of undulating hills with slate ridges and peat-filled depressions. The Rur River continues to flow in mountainous country as far as Kreuzau (km 90). From there to Juelich (also spelled as Jülich) at km 112, the terrain is hilly, but at Juelich it changes to the flat agricultural plains of the Maas (Meuse) Valley. • The Urft River originates in a deep-cut valley in the mountains near Schmitheim and joins the Olef River in the "Volcanic Eifel" region near Gemünd (Gemünd), meandering through a deep valley to the confluence with the Rur River. The Kall River has its source in the highlands of the "Hohe Venn" region and flows northward through mountainous country to its junction with the Rur River near Zerkall (km 79). Reference is made to the document listed in the Bibliography as Reference 2 for detailed topographic information.

2-03 GEOLOGY.

The Rur and Kall Rivers originate in the Eifel region, which is marked by alluvial moor formations. The Rur, Kall, and Olef Rivers, and part of the Urft River, cut their way through lower Devonian layers consisting of graywackes and schists. As the rivers emerge from the "Hohe Venn" region, they successively cross layers of graywacke, slate, sandstone and calcite, and on the line between Eschweiler and Weissweiler reach the "Bight of Juelich" with its heavy loess cover. The Urft River originates in the calcareous "ravine of Blankenheim," and crosses

• Dutch spelling is Maas, Belgian spelling is Meuse

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the Lower Devonian region to enter the calcareous "Kavine of Soestenberg" and then the mottled sandstone of the Triassic "Sicht of Kommern," with its sandstones and conglomerates. Above Gemünd, it again enters a Lower Devonian region. At least half of the area of the Urft River basin is composed of calcites, dolomites, and slates of the Middle Devonian Age. Detailed geologic information is contained in Reference 3.

2-04 DRAINAGE AREA.

The total drainage area of the Rur River is 2299 km². The extent of the drainage basin is illustrated on the Drainage Basin Map, Plate 3. Drainage areas at key gaging stations are included in Table 5. A tabulation of areas drained by the Rur River and its major tributaries follows:

<u>River</u>	<u>Location</u>	<u>Drainage Area (km²)</u>
Rur	Above mouth of Urft River	246.6
"	At Rur Dam (less Urft R.)	300.0
"	Above mouth of Kall River	709.3
"	At Obermaubach Dam	794.6
"	Above mouth of Inde River	970.9
"	Above mouth of Wurm River	1609.6
"	At Confluence with Maas R.	2299.0
Urft	At Urft Dam	375.4
Kall	At Kall Dam	29.0
"	At Rur River Confluence	77.8
Inde	At Dreilaegerbach Dam	10.9
"	At Rur River Confluence	352.4
Wurm	At Rur River Confluence	456.1

2-05 GRADIENTS AND PROFILES.

The Rur River has a very steep gradient, dropping 663 m in a distance of 160 km between its source (elevation 666 m ^{ASL}), and the German-Dutch border (elevation 22 m ^{ASL}), for an average gradient of 41 per 10,000. The mountainous upper regions of the river have gradients of as high as 300 per 10,000, while the lower reaches below Stah (km 152) have gradients averaging 10 per 10,000. Reference is made to the Rur River stream-bed profile on Plate 4 and to the following tabulation:

<u>Reach of Rur R.</u>	<u>River Km</u>	<u>Average Gradient per 10,000</u>
Urft R. - Heimbach	61-63	38
Heimbach - Zerkall	63-79	22
Zerkall - Dueren	79-98	28
Dueren - Juelich	98-115	23
Juelich - Dutch Border	115-160	12
Dutch Border - Maas R.	160-160	9

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2-06 CHANNEL DEPTHS.

The Rur River channel, exclusive of the reservoirs and retention ponds, varies in depth between 0.4 and 1.0 m at Mean Water, in the reaches located upstream from the German-Dutch border. In spite of the relatively shallow depths, fording becomes difficult at stages above MW because of the high velocities resulting from the prevailing steep gradient of the river. During flood conditions, the river may reach an average depth of above 2.5 m. Reference is made to the tabulation of depths included in Exhibit A and to the depth profile presented on Plate 10. Representative normal depths at selected points along the Rur River are given in the following table:

<u>Location</u>	<u>River Km</u>	<u>Depth at MW (m)</u>
Zerkall	79	0.6
Dueren	98	0.5
Juelich	113	0.5
Orsbeck	149	1.0

2-07 CHANNEL AND FLOOD-PLAIN WIDTHS.

Detailed information on channel and flood-plain widths are contained in Exhibit A and on Plate 5. A tabulation of representative widths along the Rur River follows:

<u>Reach of Rur River</u>	<u>River Km</u>	<u>Channel Width (m)</u>	<u>Flood-Plain Width (m)</u>
Heinbach - Zerkall	63- 81	16	-----
Zerkall - Kreuzen	81- 89	18	100-300
Kreuzen - Landerdorf	89- 93	18-20	20-300
Landerdorf - Dueren	93- 98	26-30	No overflow
Dueren - Juelich	98-113	25	400-500
Juelich - Linnich	113-126	20	300-600
Linnich - Orsbeck	126-149	18-20	300-600
Orsbeck - Dutch Border	149-160	23	500-1000

2-08 NAVIGATION.

The Rur River and its tributaries are not navigable except for a short reach near the mouth in the Roermond harbor area.

2-09 REGULATION.

Seasonal variation of flow in the Rur River is controlled to a great extent by the operation of the reservoir system in the Rur River valley. High water flows are impounded in four major storage reservoirs and two equalizing pools. The two larger dams, the Urft and Schwammensel (Rur) Dams, have storage capacities of 45.5 and 100 million m³ respectively, and are used for power generation and water supply as well as flood protection. The Kall and Dreilaegerbach Dams on tributaries of the Rur River are primarily small water-supply projects for the Aachen district.

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The storage reservoirs are normally kept at 80% capacity from April to June, at 50% capacity from August to December, and average 67% capacity during the remaining transition periods of the year. Re-regulation of discharges from the large dams and control of water levels for downstream industries is made possible by operation of the Heimbach and Obermaubach Dams. A more detailed description of the structure and operation of these dams is contained in paragraph 2-10. In order to control stream velocity and to provide industrial water to the developed reaches of the Rur River, low check dams have been installed approximately one km apart along the river. These check dams, augmented by 4 m wide channels on either side of the main stream-bed, permit withdrawal of water for industrial use from the Rur River during periods of low flow.

2-10 DAMS AND RESERVOIRS.

a. General. In the Rur River system there are seven important dams, namely: the Urft, Paulushof, Schwammenauel (Rur), Heimbach, Obermaubach, Kall, and Dreilägerbach Dams. Collectively, they are commonly known as the "Eifeltalsperren" (Eifel Reservoirs), Rur Dams, or Schmidt Dams. Table 3 provides a summation of their individual general characteristics. The geographic locations are shown on Plates 2 and 3, and sketches and photographs illustrating details of the dams are presented on Plates 6 to 9, inclusive. Detailed description is contained in Exhibits A and B which consist of translations of pertinent excerpts from German military documents and technical literature.

b. Urft Dam. In the period 1900-05, this large masonry dam was built on the Urft River, approximately 4.5 km upstream from the confluence of the Urft and Rur Rivers. It is a multiple purpose reservoir, impounding 45.5 million m^3 of water for power, water supply, and flood control. The dam structure is 226 m long, 58 m high and 50.5 m wide at its base. 30 m^3/sec can be discharged at full pool through the 3 bottom outlets into the Schwammenauel (Rur) Reservoir, and 34 m^3/sec through the 2.8 km long tunnel and penstock leading to the Heimbach Power Plant. Reference is made to Plate 6, Table 3 and Exhibits A and B for further details.

c. Schwammenauel (Rur) Dam. This is the largest dam in the Rur River valley and was built in 1935-37 to complete the regional water economy program. It is located on the Rur River at km 59.8, about 15 km below the Urft Dam. The existing reservoir capacity of 100 million m^3 supplements the Urft Dam's multiple purpose functions of power, water supply, and flood control. The Rur Dam is 300 m long, 62 m high, and 300 m wide at the base; and is of an unusual type, consisting of several layers of earth with a flexible core of steel and concrete. Provision was made in the design for future enlargement of the structure to provide double the existing storage capacity. The 2 bottom outlets can discharge about 80 m^3/sec at the existing full pool, while the spillway capacity is approximately 750 m^3/sec . Table 3, Plate 7 and Exhibits A and B contain additional information.

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d. Paulushof Dam. The small (10.5 m high) earth dam at Paulushof was built in conjunction with the construction of the Schwammenauel (Rur) Dam to regulate the water level in the upper reaches of the Schwammenauel Reservoir. It has little hydraulic significance, but primarily serves to prevent the natural beauty of the area from being impaired by unsightly exposure of mud-flats during periods of low pool levels in the Schwammenauel Reservoir. See Table 3, Plate 8 and Exhibits A and B for further details.

e. Heimbach and Obermaubach Dams. These so-called equalizing basins on the Rur River at km 63.4 and 83.9 (See Plate 2) were built in 1934 to complement the Urft and Schwammenauel Dams in regulation of the Rur River. Their functions are to equalize the discharges from the storage reservoirs and to control the water supply to the industrial regions of the Rur Valley. These two dams are respectively 9 and 7.3 m high, and have storage capacities of 1.25 and 1.65 million m³, respectively. The Heimbach Dam has a gated weir 5.5 m high and 18 m long, which provides automatic regulation of upstream stage. The dual gates of the Obermaubach Dam are each 5.5 m high and 18 m long and are similar in design and operation to the Heimbach installation. Additional detailed information appears in Table 3, on Plate 8, and in Exhibits A and B.

f. Dreilaegerbach Dam.* In 1909-11, this 43 m high by 240 m long masonry dam was built on the Dreilaegerbach, a tributary of the Vicht River, a branch of the Inde River which flows into the Rur River at km 112 near Juelich. Its sole function is to provide a portion of the water supply for the Aachen district and it impounds up to 4.3 million m³ of water. The natural drainage area was increased by construction of the Kall Dam, Kall Tunnel, and several collecting channels, as explained in detail in Exhibits A and B. Pertinent data are summarized in Table 3, and sketches of the dam are included on Plate 9.

g. Kall Dam. The Kall Dam was built to supplement the Dreilaegerbach Dam as part of the 1934-39 regional water economy program. The dam is located on the Kall River about 15 km above the Rur River confluence at km 79 near Zerkall. It is a 190 m long, 39.5 m high earth dam with a concrete core. The existing reservoir storage capacity is 2.1 million m³. After the proposed future 9.3 m increase in dam height is effected, the storage capacity would be increased to 4 million m³. (See Plate 9 and Exhibits A and B). The Kall reservoir is connected by means of 6.2 km tunnel to the Dreilaegerbach reservoir. Pertinent dam data are summarized in Table 3.

2-11 LEVEES.

The levee system of the Rur River is concentrated in the developed areas below Obermaubach (km 84). The following table extracted from Exhibit A is an indication of the extent of the flood protection levees:

* Also spelled as "Dreilaegerbach".

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Reach	River km.	Remarks
Obernambach-Kreuzen	84- 89	Revetted RR embankment on right bank.
Kreuzen-Lendersdorf	89- 93	No protection.
Lendersdorf-Dueren	93- 98	High water does not overflow banks.
Near Dueren	98-102	Dueren to Hoven is regulated.
Dueren-Juelich	102-113	No protection except for local factories, etc.
Juelich-Linnich	113-116	Flood protection on right bank at Juelich.
	116-126	No protection.
Linnich-Orsbeck	127-129	Dikes both sides.
	130-149	Dikes both sides.
Orsbeck-Stah	150-152	Flood protection Dikes both sides.

2-12 CANALS.

There are no navigation canals in the Rur River basin. The only significant canals in this area are those mentioned in paragraph 2-07b and which supply river water to the local industries. Although detailed current information on the status or location of these industrial canals is not available, it is assumed that the reach of the Rur River between Kreuzen and Orsbeck has industrial canals along both banks of the river.

These canals have a standard width of approximately 4 m and, for the most part, parallel the river channel. Reference is made to Exhibit A for information circa 1940.

2-13 BRIDGES.

Reliable information with respect to post-war bridge reconstruction was not available in this office at this time; however, a tabulation of available bridge data extracted from Reference 17 is presented in Table 4. Locations and clearances (wherever data are available) is indicated on Plate 4.

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SECTION III

HYDROLOGIC CHARACTERISTICS

3-01 GENERAL.

a. Information regarding river stage, discharge, flow duration and velocity are presented in generalized graphical form insofar as practicable to facilitate application of the data to specific military problems. The cited references should be utilized for supplementary data.

b. Most available long-term stage and discharge records in the Rur (Roer) River basin cover periods prior to completion of the present reservoir system in 1937 and consequently are not indicative of the regulatory effect of the reservoirs. Data presented in this report for the available 1937-1946 period probably reflect the general stage and discharge trends to be expected with the present reservoir system in operation.

3-02 CLIMATOLOGY.

Climatological data for the region covered by this report may be found in References 3, and 18 to 21, inclusive. The significant facts concerning precipitation in this basin are; (1) the relatively higher volume falling in the drainage area of the upper Rur, Kall and Inde Rivers when compared with the Urft River basin; (2) the periodical cycle of wet and dry years; and (3) the general decline of the mean annual runoff over the past 15 years. Reference should be made to the publication listed as Reference 3 for detailed discussion of the geographical distribution of annual runoff in the Rur River basin. A tabulation of annual mean rainfall and runoff over the drainage areas at key locations for the period 1934-43, extracted from Reference 3 follows;

<u>River</u>	<u>Location</u>	<u>Drainage Area (km²)</u>	<u>Rainfall (mm/km²)</u>	<u>Runoff (mm/km²)</u>
Rur	Rur Dam	300.0	1014	619
"	Zerkall	787.1	910	420
"	Juelich	1344.2	813	340
"	Stah	2075.8	766	280
Urft	Urft Dam	375.0	853	434
Kall	Kall Dam	29.0	1044	588
Inde	Dreilaegerbach	10.9	1011	561
"	Eschweiler	215.8	839	603
Gurm	Coilankirchen	227.6	729	292

3-03 STREAM GAGING STATIONS.

Stream gaging stations have been established on the main stem of the Rur River at Zerkall, Juelich, and Stah; on the Inde River

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at Eschweiler; and on the Wurm River at Geilenkirchen. Stage and discharge records for these stations appear in References 18 to 20, inclusive. Locations are indicated on the River Basin Map, Plate 2 and on the Rur River Stream Profile, Plate 4. Pertinent data concerning the Rur River gages are contained in Plate 5.

3-04 RIVER STAGES.

a. Records. Statistical data regarding the mean and extreme stages experienced at key gaging stations on the Rur River during the 1937-40 water-years are summarized in Table 5. Reference is made to the German Hydrologic Yearbooks, References 18 to 20, inclusive, for additional information.

b. Seasonal Variation. The mean monthly gage heights for the key Rur River gages during the 1937-40 water-years are tabulated in Table 5, and the monthly variations of stage are graphically illustrated on Plate 12. Stage durations extracted from Reference 18 are shown as Plate 11. The effect of regulation of the Rur River reservoirs for water supply of the Dueren-Juelich industries is reflected in the slight variation of stages during the summer months. While the short period of record cannot give an accurate indication of the maximum stages to be expected, this period does include a time of abundant precipitation and it is believed that the data presented provide a reasonably accurate index of the normal stages to be expected.

3-05 RIVER DISCHARGES.

a. Records. As mentioned in paragraph 3-01, the completion of the reservoir system in 1937 makes the records of discharges in this area during the period prior to that time generally unrepresentative of the present day flow. The paucity of post-war data further complicates the establishment of norms upon which to base comparisons. However, the lack of specific current discharge information is not considered a serious handicap, and consequently the derived short-term records were utilized wherever possible. Generous use was made of data given in Exhibit A and References 3, and 18 to 21, inclusive. Long-term records of mean natural discharges for areas above the damsites are shown in order to provide basis for estimates of the filling time of the reservoirs. These natural runoffs or inflows would be unaffected by construction of the dams.

b. Runoff Volume. From information contained in Reference 3, the natural runoff for the drainage areas above the major damsites is presented below. It may be seen that between 70 and 80 percent of the average yearly water supply is obtained during the first six months of the water-year; while, on the other hand, the natural flow does not satisfy the normal industrial usage during the remaining six months.

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Mean Volume of Natural Runoff (million m³)

N	D	J	F	M	A	M	J	J	A	S	O	Year
<u>Urft Dam, 375 km² (1897-1942)</u>												
29.1	26.3	30.8	23.6	24.0	19.8	10.5	5.6	5.2	5.2	6.8	10.5	188.5
<u>Schwammenauel (Rur) Dam, 300 km² (1912-1928)</u>												
20.3	30.3	39.2	22.5	20.4	17.9	12.9	6.6	6.3	6.3	9.6	12.6	204.8
<u>Obermaubach (Estimated), 795 km²</u>												
43.1	55.1	65.1	49.6	51.1	41.6	21.9	12.6	11.1	10.6	14.1	22.1	396
<u>Kall Dam, 29 km² (1926-1942)</u>												
2.1	2.3	2.6	2.0	1.8	1.9	0.8	0.5	0.6	0.6	0.5	1.2	17.3
<u>Dreilaegerbach Dam, 11 km² (1913-1942)</u>												
0.8	0.9	1.2	0.8	0.7	0.8	0.4	0.3	0.3	0.3	0.3	0.5	7.4

c. Mean Discharges. As discussed in Exhibit B, runoff in the Rur River area is subject to large seasonal variation, being very high in winter and low in summer. During the summer months the natural runoff only averages 6 to 7 liters/sec/km². Operation of the reservoir system of the Rur River regulates the flow so as to insure about 9 m³/sec to meet the water requirements of the industrial regions below Heimbach. For purposes of comparison, mean monthly and annual discharge rates (corresponding approximately to natural runoff or inflow rates) for the areas above the damsites as derived from basic data in Reference 3 are tabulated below, together with regulated discharge rates for key locations downstream of the reservoirs as extracted from Reference 18. It may be noted in the following tabulation that the minimum mean monthly rates at Zerkall and Juslich are less than the 9 m³/sec industrial requirements. This seeming discrepancy is probably due to the difference between average flow and peak usage of industrial water during working hours or to diversion of water through the industrial canals mentioned in paragraph 2-12.

Mean Monthly and Annual Discharge (m³/sec)

N	D	J	F	M	A	M	J	J	A	S	O	Year
<u>Reservoir Inflow Rates</u>												
<u>Urft Damsite 375 km² (1897-1942)</u>												
7.9	15.1	12.2	8.5	9.6	7.6	4.2	2.2	2.1	2.1	2.5	4.2	6.1

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Schwanenauel (Rur) Damsite 300 km² (1912-1922)

7.8 12.1 14.3 8.1 8.1 7.0 5.1 2.6 2.5 2.5 3.7 5.0 6.6

Übermaubach Damsite 795 km² (1897-1942) estimated

15.6 20.5 24.2 20.5 19.1 16.2 8.3 4.6 4.1 4.1 5.4 8.3 12.7

Kall Damsite 29 km² (1926-1942)

0.8 0.9 1.0 0.9 0.7 0.8 0.3 0.2 0.2 0.2 0.2 0.5 0.6

Dreilaegerbach Damsite 11 km² (1913-1942)

0.3 0.4 0.5 0.3 0.3 0.3 0.2 0.1 0.1 0.1 0.1 0.2 0.2

Regulated Stream Discharge Rates

Zerkall 787 km² (1937-1940)

11.3 17.0 18.0 23.0 18.5 20.0 10.0 7.0 7.0 7.0 7.0 7.5 12.8

Juelich 1344 km² (1937-1940)

12.0 18.0 20.0 31.0 20.0 23.0 9.5 5.0 4.0 6.0 7.5 7.5 13.6

Stah 2066 km² (1937-1940)

17.5 23.5 26.5 35.0 28.5 28.0 16.5 11.5 10.5 10.5 11.5 11.0 19.2

d. Maximum Discharges. The maximum discharges of record, derived from data in Exhibit A and References 3 and 20, are tabulated below. It should be noted that these values represent estimated, rather than observed rates of discharge, and that certain discrepancies are apparent (probably due to different periods of records being utilized by the various sources).

Maximum Discharges-Rur River

Station	Drainage Area (km ²)	Date	HHQ (l/sec/km ²)	HHQ (m ³ /sec)
Urft Dam	375	Unknown	550	206
Rur Dam	300	"	1437	430
Heimbach	675	"	620	418
Zerkall	787	12 Jan 1920	355	280
Juelich	1344	12 Jan 1920	208	280
Stah	2066	31 Dec 1925	242	500

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3-04 RIVER VELOCITIES

a. General. The velocity of stream flow varies according to the conformation of the river bed, depths, obstructions, restrictions, local variation of slope, etc. Channel improvements and cut-offs, training walls and levees, operation of dams and other modifications of natural conditions appreciably affect the stream velocity. Influent rivers in flood tend to elevate the main river waters at the point of confluence according to the magnitude of the flood, thus tending to reduce the slope above and to increase it below the point of confluence. Accordingly, correlations between river stages and surface velocities at gaging stations cannot be interpreted as applicable to all points along the adjacent river sections, but only serve as general indications.

b. Surface Velocities. Insufficient basic information concerning the stream hydraulic functions (cross-sectional area, wetted perimeter, water surface slope, roughness factor, etc.), was available to permit accurate determination of stream velocities. Estimates were based on velocities observed during discharge measurements at gaging stations as recorded in Reference 19. The observed velocities were assumed to be mean cross-sectional velocities, which were increased by 18 percent to indicate the mean surface velocity. As indicated in the velocity studies in Reference 22, the mean cross-sectional velocities should be increased by 25 to 75 percent to obtain the maximum surface velocities likely to be encountered during crossing operations. Mean cross-sectional velocity durations are illustrated on Plates 11 and 12. Mean surface velocity ratings at the gaging stations are shown in Plate 13. Mean surface velocities at selected stations, as shown on Plate 10, are tabulated below:

Mean Surface Velocities (m/sec)

<u>Station</u>	<u>River Km</u>	<u>MF</u>	<u>MFV (Exhibit A)</u>
Zerkall	79	0.9	3.0
Juelich	115	0.7	2.7
Stah	152	0.7	1.7

c. Flood Wave Travel Time. Examination of flood crest times as recorded in the official German Hydrologic Yearbooks (References 18, 19, 20) provided the following estimate of travel time and rate of travel of natural flood waves on the Rur River:

<u>Reach</u>	<u>River Km</u>	<u>Average travel (time-hrs.)</u>	<u>Average travel rate of peak (km/hr.)</u>
Zerkall-Juelich	79-115	8.0	4.5
Juelich-Stah	115-152	11.5	2.5

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SECTION IV

ARTIFICIAL FLOODING POTENTIALITIES

4-01 GENERAL.

a. The term "artificial flood" as used in this report applies to any major increase in the extent of flooding, over that normally prevailing with existing developments, that is brought about by manipulation of control structures, breaching of dams or levees, or temporary damming operations designed to create flooding conditions. Applications of artificial flooding considered in this report fall into the following four general categories:

(1) Still-water barriers, created by flooding land to form water obstacles, using such means as breaching levees, diverting flow from canals, raising crests of existing dams or constructing temporary dams.

(2) Drainage obstacles or mud-flats, in which the wetness of the soil is increased to form muddy or marshy conditions that would impede military traffic, brought about by disrupting the normal drainage, destroying pumping and drainage facilities used to drain marshy or low land, or by inducing shallow inundation of flood-plains or reclaimed land. Mud-flats may also be formed by draining areas normally inundated by reservoirs or ponds.

(3) Stream flow variations, in which changes in discharges, depths, velocities and widths of streams are brought about to hinder stream-crossing operations or navigation such as might be accomplished by opening and closing outlet works of water control structures.

(4) Major flood waves, created by sudden breaching of a dam to release large quantities of impounded water.

b. Opportunities exist for effective use of each of the four general categories of artificial flooding. The potentialities are reviewed and quantitative evaluation of the effects are presented in this section.

c. Previous studies by German and Allied military staffs indicate the nature and extent of possible artificial flooding. The document listed in the Bibliography as Reference 1, a translation of which is included in this report as Exhibit A, was prepared for the German General Staff and contains considerable information on the effects of artificial floods. The information contained in that document formed the basis for "Estimates of the Situation" and planning by both German and Allied staffs during the Rur (Roer) River crossings of World War II, as illustrated in the document listed as Reference 23.

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d. The possibility of a flood wave induced by the destruction of Schwammenauel and Urft Dams by the Germans to hinder the Allied crossing of the Rur River, and the actual German demolition of the outlets of these dams had a great effect upon tactical operations by both the German and Allied forces. A detailed account of that operation is contained in Reference 24, a VII Corps report included as Exhibit 2 of this report. Reference is also made to References 23 and 25 for additional information.

4-02 STILL-WATER BARRIERS AND DRAINAGE OBSTACLES.

a. General. The studies herein reviewed in this paragraph pertain to artificial flooding produced by creation of still-water barriers and drainage obstacles along the Rur River below the Schwammenauel (Rur) Dam. The studies were largely based on a map study, using the 1:25,000 GSGS 4414 map series. Exact determination of elevations, contours, and boundaries from these maps was difficult; however, the results of this study are believed to offer good indications of the relative possibilities of such flooding. First-hand information should be obtained by local reconnaissance regarding ground elevations and the locations, elevations and dimensions of levees, roadfills and culverts in the vicinity of specific barriers in order to accurately establish the area subject to artificial flooding.

b. Hydrologic Considerations. The effect of artificial flooding is largely contingent upon the natural hydrologic conditions prevailing at the time of the operation. The volume of water stored and available within the basin, the rate of stream flow and the river stage are important factors. Reference is made to Section III of this report for detailed description, and to the following summation of pertinent hydrologic considerations.

(1) Attention is directed to the wide range between high and low flows and to the seasonal variation in discharge shown in Table 5 and Plates 10 to 12, inclusive and discussed in paragraph 3-05. The annual average mean discharges are tabulated below:

<u>Reach</u>	<u>Average Mean Discharge (m³/sec)</u>
Heimbach-Dueren	12
Dueren-Juelich	13
Juelich-Orsbeck	16
Orsbeck-Mass R.	20

(2) A plentiful supplementary water supply is afforded by the 150 million m³ storage capacity of the existing reservoirs located within the drainage area. During extended dry periods, the volume of stored water available for artificial flooding would be considerably reduced.

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c. Means of Creating Still-Water Barriers and Drainage Obstacles.

(1) The water obstacle afforded by the existing streams of the Rur River basin could be increased by utilization of one or more of the following means:

(a) Creation of still-water barriers by raising crests of existing dams or by construction of temporary dams, combined with closing of culverts and other openings in levees and road fills.

(b) Inundation of lowlands along the streams by breaching dikes and levees and opening of flood gates in levees.

(c) Inundation of lowlands by closing normal drainage outlets.

(2) In order to obtain a comparative quantitative evaluation of the potential artificial flooding at various locations, analysis was arbitrarily confined to still-water barriers resulting from temporary damming to 3 m above mean water (MW). In this study, it was assumed that the water surface of the pools above the temporary dams would be level, and that mean water conditions would prevail at the time of the operation. During high water conditions, greater flooding could be expected due to the increased slope of water surface upstream from the temporary dams.

d. Effect of Still-Water Barriers.

(1) General. The effects of artificial flooding created by temporary damming operations on the Rur River are summarized in Table 6 and the extent of inundation outlined on Plate 14. Serial numbers of sites correspond to bridge serial numbers of Table 4. The flooding produced by the temporary damming would cover isolated areas about 0.1 to 0.6 km wide. Formation of continuous overbank flooding would not be practicable except during periods of high flows. Insufficient data regarding the existing small check dams along the river were available to permit analysis of the possibility of increasing their height, but it appears probable that the resulting overbank flooding would be slight. Review of the effects of still-water barriers in specific reaches of the Rur River follows.

(2) Heimbach (Km 63) to Dueren (Km 98). Temporary damming at the 2 bridges in Untermuibach (km 85.3 and 85.6) and at the Udingen bridge (Serial 25) could produce a still-water barrier practically continuous for about 3 km, and averaging 100 to 200 m wide as shown in Table 6. As illustrated on Plate 14, the only other suitable site in this reach is at Kreuzau (Serial 26), at which location, damming would have to be carried to the height of the road embankment in order to be effective.

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(3) Dueren to Juelich (Km 115). In the upper part of this reach, two suitable still-water barrier sites exist; the Weisenau railroad bridge (Serial 31) and the Autobahn bridge (Km 101.4). Inundation of areas 1 km long and 100 to 200 m wide to an average depth of about 0.5 m could be produced by temporary dams at these locations. At the extreme lower end of this reach, a continuous barrier about 2.5 km long, 150 to 500 m wide, and averaging about 0.7 m deep could be produced by temporary damming operations at the 3 Juelich bridges (Serials 35, 36, and 37). As indicated in Table 6 and on Plate 14, no other suitable sites for significant flooding exist in this reach.

(4) Juelich to Orsbeck (Km 149). Significant flooding could be effected at Baal (Serial 43) and Orsbeck (Serial 47) by temporary dams at these bridges. Inundation of areas about 2 km long and 600 m wide to an average depth of 0.5 m at each of these locations could be produced. See Table 6 and Plate 14. Otherwise there are no suitable sites for significant still-water barriers in this reach.

(5) Orsbeck to Meas River. No significant flooding could be produced in this reach by means of temporary damming operations during other than periods of extremely high flows in the river.

e. Water Requirements for Still-water Barriers.

(1) Approximately 2.5 million m^3 of water would be required to effect the artificial flooding described in the preceding paragraph and shown in Table 6 and on Plate 14. The still-water barriers in the vicinity of Juelich, Baal, and Orsbeck would account for about 2 million m^3 of that required volume and could be filled in about 36 hours, at the normal mean rates of flow given in paragraph 4-02b. The remainder of the volume could be furnished in approximately 12 hours at these rates, thus corresponding to a total estimated time of filling of 48 hours.

(2) The volume stored in the reservoirs, about 150 million m^3 , could be made available for supplying water for the still-water barriers. The combined outflow from the Schwammenauel, Urft, Kall and Dreilagerbach Dams is approximately 140 m^3 /sec under full pool conditions. Studies described in paragraph 4-04 indicate that it would take about 12-15 hours for the initial increase in flow to travel downstream to the vicinity of Orsbeck, plus about 60 hours for the flow there to reach the maximum sustained rate.

4-03 MAJOR FLOOD WAVES.

a. General. The studies in this paragraph pertain to the artificial flooding that might be produced along the Rur River

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by breaching of the Schwarzenauel (Rur), Urft, Kall and Dreilaegerbach dams. Breaching of the Heimbach and Obermaubach Dams was not considered, because the effect would be but slightly greater than that produced by the sudden opening or demolition of their large weir gates discussed in paragraph 4-04. Reference is made to paragraph 2-10 and to Exhibits A and B for descriptive data and to Plates 6 to 9, inclusive, for sketches and photographs of the dam structures.

b. Hydrologic Considerations.

(1) The Rur River stages are regulated by operation of the reservoirs to increase flow during dry periods and to reduce flood flows during wet periods. In study of the effect of major flood waves on the Rur River, it was assumed that the base flow in the stream at the start of the wave approximated a mean water flow of $10 \text{ m}^3/\text{sec}$, comprised of $5 \text{ m}^3/\text{sec}$ constant inflow into the Urft Reservoir and $5 \text{ m}^3/\text{sec}$ flow in the Rur River above the Urft River confluence.

(2) Peaks and durations of artificial flood waves are greatly influenced by the initial reservoir pool level and storage capacity of the reservoir. In this study it was assumed that, for most of the artificial floods studied, the reservoirs were at the maximum level in order to define the maximum probable limits of the flood waves. However, a number of floods resulting from breaching of the dams when the reservoirs were filled to one-half of their maximum capacity were studied in order to illustrate the effect of partial filling of the reservoirs upon artificial flood waves. As noted in Exhibit A, the reservoirs are generally only one-half full from August to December, $4/5$ full from April to June and in the other months filled to $2/3$ capacity. Only after a heavy rain or in time of melting snow do the pool levels exceed the full or spillway elevation. Following is a tabulation from Plates 15 and 16 of the reservoir levels corresponding to full and one-half full capacity:

<u>Dam</u>	<u>Full Pool</u>		<u>1/2-Full Pool</u>	
	Capacity <u>10^6 m^3</u>	Elevation <u>m A.S.L.</u>	Capacity <u>10^6 m^3</u>	Elevation <u>m A.S.L.</u>
Urft	45.5	322.5	27.75	311.5
Palushof	1.75	263.0	0.87	260.3
Schwarzenauel	100.0	265.5	50.0	252.5
Heimbach	1.25	214.0	0.62	211.2
Obermaubach	1.65	165.0	0.82	163.0
Kall	2.1	421.5	1.05	414.5
Dreilaegerbach	4.28	392.6	2.14	386.0

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The reservoir storage curves shown on Plates 15 and 16 were developed by the method presented in Reference 26. The resulting equations for the storage curves can be expressed as:

$$S = CH^n$$

Where S equals storage volume in m^3 , H equals reservoir depth in m, and where C is a coefficient and n an exponent. The values of C and n as computed for the various reservoirs follow:

<u>Reservoir</u>	<u>C</u>	<u>n</u>
Urft	5,350	2.27
Paulushof	8,320	2.26
Schwammenauel (Rur)	11,100	2.35
Weinbach	21,900	1.84
Obermaubach	19,200	2.23
Kall	49.7	3.02
Dreilaegerbach	90.2	3.08

(3) During passage of a major flood wave downstream, an appreciable amount of volume is retained behind embankments and in depressions on the flood-plain, and lost through evaporation, seepage, etc. For example, 39.5 percent of the volume of water discharged from the Eder Dam breach of May 1943 was lost in the passage of the flood wave to Intschede, 426.6 km below the dam (See References 27 and 28). Consequently it was assumed in this study that for each 10 km of travel, about 1 percent of the volume within the flood wave would be lost or retained on the flood-plain.

c. Means of Creating Major Flood Waves.

(1) Major artificial flood waves can be created on the Rur River by breaching of the Urft and Schwammenauel Dams, on the Kall River by breaching of the Kall Dam, and on the Vicht and Inde Rivers by breaching of the Dreilaegerbach Dam.

(2) The bombing of the Mohne, Gorpe, and Eder Dams by the R.A.F. in May 1943 (described in Reference 19) provided the basis for estimating the size and shape of breach. For purpose of this study, it was assumed that demolition would cause an opening similar to that produced by the Eder Dam bombing.

(3) The assumed breach approximates a parabolic shape, corresponding closely to the equation:

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x^2 equals $51 y$

where x equals horizontal distance from vertical axis
of the opening

y equals vertical distance above lowest point
of breach opening

It was considered that the assumed breach approximates the largest feasible opening likely to be produced in the Urft, Schwammenauel, Kall and Dreilaegerbach Dams. Breaching of earth dams with steel or concrete cores like the Schwammenauel and Kall Dams would require special preparations and procedures as described in Reference 27.

(4) In order to permit comparative evaluation of the artificial flood waves it was assumed that the lowest point of the breach was 23 m below the normal full pool water surface (similar to the Eder Dam breach) for large breaches designated in this study as "Breach I" and 10 m below full pool level for smaller breaches designated as "Breach II." At the water surface, the length of opening of Breach I would be about 68 m and of Breach II would be 45 m.

d. Effects of Dam Breaching Operations.

(1) General. The estimated effects of artificial flood waves on the Rur River produced by breaching of the storage dams are summarized in Tables 7, 8, and 11, and typical discharge hydrographs at key locations are presented on Plates 17 and 18. The artificial floods studied are described in subsequent paragraphs. The various major flood waves are designated as follows:

<u>Artificial Flood No.</u>	<u>Dam Breached</u>	<u>Type of Breach</u>	<u>Pool Conditions</u>
1	Urft	I	Full
2	"	II	"
3	Rur	I	"
4	"	I	1/2 Full
5	"	II	Full
6	Urft & Rur	I	"
7	"	I	1/2 Full
8	Urft	I	(Urft-Full) (Rur-Empty)
9	Kall	II	Full
10	Dreilaegerbach	II	"

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(2) Artificial Flood No. 1 results from large sized breaching (Breach I) of the Urft Dam when the reservoir of both Urft and Schwarzenauel (Rur) Dams are full, the resulting wave passing over the fixed spillway and opened spillway weir gate of the Rur Dam. (See Sketches of Dams, Plates 6 and 7). The spillway capacity of the Rur Dam is sufficient to permit the passage of this wave without overflowing the crest of the dam. The peak discharge of 8500 m³/sec from the Urft Dam breach would be reduced to 1250 m³/sec during its passage through the Schwarzenauel (Rur) reservoir, and would decrease to 740 m³/sec at Stah and to 600 m³/sec at the confluence of the Rur and Maas Rivers. Discharge hydrographs at key locations are shown on Plate 17 and the effects are tabulated in Table 7. Plate 10 shows the depth, discharge and velocity resulting from Flood No. 1 compared to natural values.

(3) Artificial Flood No. 2 results from smaller sized breaching (Breach II) of the Urft Dam during full pool conditions. The peak breach discharge of 1000 m³/sec would be reduced to 360 m³/sec during its passage through the full Rur reservoir pool and over the spillway and opened weir of the Rur Dam. Peak discharge would be only 252 m³/sec at Stah and 224 m³/sec at the Maas River junction, as shown in Table 7.

(4) Artificial Flood No. 3 discharge hydrographs shown on Plate 17 result from large sized breaching (Breach I) of Schwarzenauel (Rur) Dam when the reservoir is full. The peak discharge of 8500 m³/sec at the dam would reduce to 2660 m³/sec at Stah or 2000 m³/sec at the Maas River, as shown on Plate 17 and in Table 7. The width of flooding during the peak of the flood is shown on Plate 5.

(5) Artificial Flood No. 4 would result from the large Breach I in Rur Dam when the reservoir was filled to 1/2 of full capacity. In this case, as shown in Table 7, the peak discharge at the dam would be only 1100 m³/sec which would decrease to 375 m³/sec at the Maas River, illustrating the influence of initial reservoir stage upon breach discharge, when compared to Flood No. 3.

(6) Artificial Flood No. 5 is the result of the smaller sized Breach II in Rur Dam under full pool conditions. Table 7 shows that the peak discharge at the dam of 1000 m³/sec would reduce to 385 m³/sec at the Maas River, approximating the results of Flood No. 4.

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(7) Artificial Flood No. 6 is produced by simultaneous breaching of both Urft and Rur Dams with openings corresponding to Breach I under full pool conditions in both reservoirs. The resulting 8500 m³/sec peak discharge at the breached dams would produce the maximum peak of the various flood waves studied. As shown in Table 7, peak discharge would be 2850 m³/sec at Stah and 2180 m³/sec at the confluence of the Rur and Maas Rivers. This is the largest of the artificial floods studied.

(8) Artificial Flood No. 7 differs from Flood No. 6 in that the reservoir storage was assumed to be at 1/2 of full capacity, resulting in great diminution of discharge. A peak discharge of 1750 m³/sec would issue from the breached Urft Dam and 1130 m³/sec from Rur Dam. The flow at Stah would be 635 m³/sec and at the Maas River 535 m³/sec. (See Table 7).

(9) Artificial Flood No. 8 would result from breaching (Breach I) of Urft Dam at a time when that reservoir was full and at some time subsequent to drawing down of Rur Reservoir due to a previous Breach I opening in the Rur Dam. This flood might be considered as a sequel to Flood No. 3 and illustrates the cyclic effect attainable by progressive breaching of those two dams. (Another cyclic combination could be Flood 1 followed by Flood 3). The Flood No. 8 initial peak discharge of 8500 m³/sec at the Urft Dam would be diminished to only 540 m³/sec after passing through the partially filled Rur Reservoir, resulting in flows of 352 m³/sec and 306 m³/sec at Stah and the Maas River confluence, respectively, as shown in Table 7.

(10) Artificial Flood No. 9 discharge hydrographs are presented on Plate 18 and the effects are summarized in Table 8, showing the results obtainable by the smaller sized breaching (Breach II) of the Kall Dam, located on a tributary of the Rur River. (See Plate 9 for sketch of that dam). The 1000 m³/sec peak discharge at the dam would be reduced to 300 m³/sec in passage to the confluence of the Kall and Rur Rivers near Zerkall, 15 km below the Kall Dam. Due to the small capacity of the reservoir, the duration of the flood wave would be less than 6 hours as may be seen on Plate 18 and in Table 8.

(11) Artificial Flood No. 10 is, similarly, the result of the smaller Breach II at Dreilaegerbach Dam, located 37 km from the Rur River up the Vicht and Inde River. See Plate 2 for location and Plate 9 for sketch of the dam. The discharge hydrographs plotted on Plate 18 and the summary of effects tabulated in Table 8 show that the resulting flow at the Rur River near Juelich would reach a peak of only 222 m³/sec and that the duration of the wave would be short.

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e. Comparison of Effects of Dam Breaching Operations. The comparative peak values and durations of the various flood waves produced by dam breaching operations are summarized in Tables 7 and 8 and the resulting widths of flooding during passage of the peak of the waves are tabulated in Table 11. The relation of representative artificial flood waves to natural conditions is graphically illustrated on Plates 5 and 10. Extracts of pertinent effects from Tables 7, 8 and 11 at selected key locations are presented below to facilitate comparison between the various artificial floods:

Flood No.	Disch. m^3/sec	Stage m	Peak Values			Duration	
			Mean Surf. Vel. m/sec	Arrival Time Hour	Width Flooded Km	Above 100 m^3/sec Days	Above 30 m^3/sec Days

(1) At Zerkall, Km 79

1	1085	177.7	3.5	4	0.1	1.5	3.5
2	330	175.4	3.0	6	"	1.5	3.5
3	5260	182.4	4.3	2	"	1.0	1.5
4	745	176.9	3.3	3	"	1.0	1.5
5	700	175.8	3.3	3	"	1.5	3.0
6	5510	182.6	4.3	2	"	2.0	3.0
7	920	177.3	3.4	4	"	1.5	3.0
8	480	176.1	3.2	5	"	1.0	2.5
9	300	175.2	3.0	2	"	(2 hrs.)	(3 hrs.)
10	—	—	—	—	—	—	—

(2) At Juelich, Km 116

1	960	81.6	2.9	8	0.9	1.5	3.5
2	288	79.8	2.6	12	0.1	1.5	3.5
3	3610	82.8	3.1	5	1.8	1.0	1.5
4	580	81.0	2.8	8	0.5	1.0	1.5
5	560	81.0	2.8	9	0.5	1.5	3.0
6	4000	82.8	3.1	5	1.8	2.0	3.0
7	755	81.3	2.9	9	0.9	1.5	3.0
8	400	80.4	2.7	11	0.3	1.0	2.5
9	170	79.1	2.3	4	0.1	(5 hrs.)	(6 hrs.)
10	222	79.5	2.4	11	0.1	(3 hrs.)	(5 hrs.)

(3) At Stah, Km 152

1	740	33.5	1.3	15	1.7	1.5	3.5
2	252	33.3	1.2	18	1.4	1.5	3.5
3	2660	35.1	1.3	10	2.4	1.0	1.5
4	465	33.4	1.2	14	1.7	1.0	1.5
5	465	33.4	1.2	15	1.7	1.5	3.5
6	2850	35.1	1.3	10	2.4	2.5	3.0
7	635	33.5	1.3	15	1.4	1.5	3.0
8	352	33.3	1.2	17	1.4	1.5	2.5
9	—	—	—	—	—	—	—
10	146	33.1	1.2	15	2.6	(7 hrs.)	(10 hrs.)

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4-04 STREAM FLOW VARIATIONS.

a. General.

(1) The studies in this paragraph pertain to the artificial flooding effects that might be produced by release of water from the outlets of the Urft, Schwammenauel (Rur), Heimbach, Obermaubach, Kall and Dreilaagerbach reservoirs.

(2) Included are quantitative estimates of the potential effects of detrimental flow variation produced by operation of the existing outlets and by modification of the outlet structures to increase the discharge capacity.

(3) Reference is made to paragraph 2-10 and Exhibits A and B for descriptions of the structures, to Plate 2 for locations, to Plates 6 to 9 for sketches of the dams, and to documents listed as References 4 to 16, inclusive, in the Bibliography of this report for detailed descriptions and drawings of the dams and their outlet structures.

(4) Flow variations may be repeated to produce cyclic effects, dependent upon the replenishment of the depleted storage in the reservoirs.

b. Hydrologic Considerations. Reference is made to paragraph 4-03b for discussion of the influence of natural stream discharge and initial reservoir pool level on artificial flooding.

c. Means of Creating Detrimental Flow Variations.

(1) General. Detrimental flow variations may be produced downstream from the Rur River dams by one of the following two methods:

(a) Type A, operation of the existing controlled outlets for sustained or cyclic discharge.

(b) Type B, modification of the outlets to increase discharge capacity, accomplished by temporary by-passing, alteration, demolition or dismantling of restrictions, machinery or other outlet appurtenances.

(2) Urft Dam Outlet Discharges.

(a) Type A. The three existing outlets beneath the dam have a combined capacity of about 30 m³/sec when the reservoir is full, discharging into Schwammenauel (Rur) Dam reservoir pool. The tunnel and penstock from the Urft reservoir to the Heimbach Power Plant can carry 34 m³/sec under full pool conditions. Reference is made to Exhibits A and B for detailed descriptions and to Plate 6 for a photograph and sketches of the Urft Dam outlets.

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(b) Type B. Removal of the valves and a short length of conduit pipe downstream of the concrete plug in the bottom outlet tunnels would effect an increase in the discharge capacity of these three outlets to about $44 \text{ m}^3/\text{sec}$. See Figures II and III of Plate 6. Removal or bypassing of the turbines in the Heimbach Power Plant and breaking of the penstock would increase the capacity of the power outlet to about $36 \text{ m}^3/\text{sec}$ under full pool conditions. However, under lesser pool elevations, such action could result in drastic decrease of the capacity by elimination of siphonic action, thus reducing the effective head. The demolition of this penstock by the Germans before their retreat from the locality resulted in a low rate of discharge from this source, according to eyewitness accounts.

(3) Paulushof Dam Outlet Discharges. As explained in Exhibits A and B, the Paulushof Dam serves only to prevent the upper reaches of the Schwammenauel reservoir from being subject to great fluctuations in extent of inundation, and serves more for an esthetic than a hydraulic purpose. The large spillway gates shown in Figure II of Plate 8, have a capacity far in excess of the Schwammenauel normal outlets. Consequently, no analysis was made of the possible effect of discharge from this dam as the critical control point would be at the outlets of the main Schwammenauel Dam.

(4) Schwammenauel (Rur) Dam Outlet Discharges.

(a) Type A. The outlet tunnel of the Schwammenauel (Rur) Dam, shown on Plate 7, has a discharge capacity at full pool of about $80 \text{ m}^3/\text{sec}$, as described in Exhibits A and B.

(b) Type B. Destruction of the control valves and pipes at the exit of the outlet tunnel (Figures III and V, Plate 7) would increase the discharge capacity at full pool to about $135 \text{ m}^3/\text{sec}$. Sudden opening or demolition of the 9 m wide weir gate in the spillway would increase the peak combined discharge capacity at full pool to approximately $305 \text{ m}^3/\text{sec}$. Since the crest of this gated weir is only 4 m below the full pool elevation, the duration of discharge through the weir opening would not exceed about 24 hours. Reference is made to Plate 7 and to the detailed description contained in Exhibits A and B. The outlet exit valves and entrance gate were blasted by the Germans upon their retreat as described in Exhibits B and C. The reservoir was only partly full at the time and the estimated discharge computed by the Allies at that time was approximately $91 \text{ m}^3/\text{sec}$.

(5) Heimbach and Obermaubach Dams--Outlet Discharges. The outlets of Heimbach and Obermaubach Dams are similar, both consisting of large flap gates hinged at the bottom, as shown on Plate 8 and described in Exhibits A and B. In addition both have a small bottom gated outlet. Upon sudden opening at full pool, approximately $407 \text{ m}^3/\text{sec}$ can be discharged from Heimbach Dam and $500 \text{ m}^3/\text{sec}$ from Obermaubach Dam.

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(6) Fall Dam Outlet Discharges.

(a) Type A. The two existing bottom outlets have a combined discharge capacity of $15 \text{ m}^3/\text{sec}$ at full pool. The spillway is of the fixed overflow type. Reference is made to the sketches on Plate 9 and to Exhibits A and B for further detail.

(b) Type B. The discharge capacity could be increased to about $37 \text{ m}^3/\text{sec}$ at full pool by means of destruction of the valves in the outlet tunnel and removal of a short section of the 2 outlet pipes immediately downstream of the concrete core of the dam. (See Figure V, Plate 9). It is possible that further increase in discharge might be effected by breaching or demolition of the round spillway tower, shown in Figure I of Plate 9; however, insufficient data were available regarding its detailed construction to permit inclusion in this report of the possible effects of such action.

(7) Dreilaegerbach Dam Outlet Discharges.

(a) Type A. The bottom outlet has a design discharge capacity of $12 \text{ m}^3/\text{sec}$ under full head; although in normal operation, the full capacity is not utilized due to vibration in the faulty valve as discussed in Exhibit B. A plan and cross-section of the Dreilaegerbach Dam showing the outlets is included on Plate 9 and description is contained in Exhibits A and B.

(b) Type B. A slight increase in discharge capacity of the bottom outlets to $16 \text{ m}^3/\text{sec}$ at full pool could be effected by removal of the valves and short sections of the outlet pipe near the concrete plug in the outlet tunnel. (See Figure III, Plate 9).

d. Effects of Detrimental Flow Variations.

(1) General. The effects of the detrimental flow variations produced by release of discharge from the outlets of the various Rur River dams are summarized in Tables 8 to 11, inclusive. Plates 19, 20, and 21 show representative discharge hydrographs at key locations. The artificial floods studied are individually described in subsequent sub-paragraphs. For purposes of identification, the artificial floods resulting from flow variations are designated herein as follows:

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<u>Artificial Flood No.</u>	<u>Dam</u>	<u>Type of Outlet Discharge</u>	<u>Initial pool conditions</u>
<u>Urft & Rur Dams</u>			
11	Rur	A: Normal outlets	Full
12	"	"	1/2 Full
13	"	B: Enlarged	Full
14	"	"	1/2 Full
15	Urft & Rur	*A-1: Normal	Full
16	"	*A-2: "	"
17	"	*A-1: "	1/2 Full
18	"	*A-2: "	1/2 "
19	"	*B: Enlarged	Full
20	"	"	1/2 Full
21	"	"	Urft-Full
<u>Heimbach & Obermaubach Dams</u>			
22	Heimbach	A: Sudden opening	Full
23	(Heimbach & Obermaubach)	A: Synchronized opening	"
24	"	A: Delayed opening	Heim.-Full Ober.-Empty
25	Obermaubach	A: Sudden opening	Full
<u>Kail & Dreilaegerbach Dams</u>			
26	Kail	A: Normal outlets	Full
27	"	B: Enlarged	"
28	Dreilaegerbach	A: Normal	"
29	"	B: Enlarged	"

*Type A-1 & B: Urft Dam bottom outlets and power tunnel plus Rur Dam outlets

Type A-2: Urft Dam power tunnel only plus Rur Dam outlets

(2) Flow Variations Created by Urft and Rur Dams.

(a) Artificial Flood No. 11 corresponds to the flow variation created by sustained (Type A) discharge from the existing normal bottom outlets of Rur Dam under initial full pool conditions as described in paragraph 4-04c(4). The peak discharge at the dam of 80 m³/sec would be only slightly diminished at downstream locations, decreasing to 76 m³/sec at the mouth of the Rur River, as summarized in Table 9.

(b) Artificial Flood No. 12 differs from Flood No. 11 in that initial discharge was assumed to occur when the Rur reservoir is at 1/2 full capacity. The initial peak outlet discharge of 70 m³/sec at the dam would be reduced to 64 m³/sec at the Maas River confluence as shown in Table 9.

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(c) Artificial Flood No. 13 would result from sustained (Type B) discharge from the enlarged outlets and from the opened spillway weir-gate of Rur Dam under initial full pool as described in paragraph 4-04c(4). The initial peak discharge of $305 \text{ m}^3/\text{sec}$ would rapidly diminish to $130 \text{ m}^3/\text{sec}$ in about 24 hours as the pool stage dropped to the crest of the weir, and then decrease at a slower rate to empty the reservoir in about 12-13 days. The peak discharge at the Maas River confluence would be $195 \text{ m}^3/\text{sec}$. See tabulated effects in Table 9.

(d) Artificial Flood No. 14 results from discharge from the enlarged bottom outlets of Rur Dam when the initial reservoir stage corresponds to 1/2 full storage capacity. Table 9 summarizes the effects. The peak discharge would be $117 \text{ m}^3/\text{sec}$ at the dam and $107 \text{ m}^3/\text{sec}$ at the Maas River and the duration of the wave would be about 5 days less than that of Flood No. 13, illustrating the effect of initial pool level upon the discharge from the dam.

(e) Artificial Flood No. 15 represents the resulting flow variation created by simultaneous discharge from the existing normal bottom outlets and power tunnel of both Urft and Rur Dams. The combined peak flow at Heimbach would be $114 \text{ m}^3/\text{sec}$ and at the Maas River $109 \text{ m}^3/\text{sec}$. As may be noted in Columns 13 and 14 of Table 9, the duration of the wave above $100 \text{ m}^3/\text{sec}$ would be about 9 days and above $30 \text{ m}^3/\text{sec}$ would be about 24 days as compared to the respective values of zero days and 21 days shown for Flood No. 11 discharges from the Rur Dam.

(f) Artificial Flood No. 16 is similar to Flood No. 15 except that it was assumed that the bottom outlets of Urft Dam would be kept closed until the pool had receded to the elevation of the intake of the Urft Dam-Heimbach Power Tunnel. As may be noted in Table 9, no difference in peak discharge would result; however, Flood No. 16 would be sustained above $100 \text{ m}^3/\text{sec}$ (approximately bank-full flow) about 1 day longer than Flood No. 15, but would be of about 3 days less duration above $30 \text{ m}^3/\text{sec}$.

(g) Artificial Flood No. 17 is the result of discharge from all the normal outlets and power tunnel of both Urft and Rur Dams like Flood No. 15, but with the reservoirs initially at 1/2 full capacity. The peak flow at Heimbach would be $102 \text{ m}^3/\text{sec}$ compared to $114 \text{ m}^3/\text{sec}$ for Flood No. 15, but the duration of flow would be only 1 to 2 days above $100 \text{ m}^3/\text{sec}$ and 15 days above $30 \text{ m}^3/\text{sec}$. (See Table 9). Representative hydrographs for this artificial flood are presented on Plate 19 and a graph of widths of flooding is shown on Plate 5. This flood approximates the conditions described in paragraph III-1a of Exhibit A.

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(b) Artificial Flood No. 18 is the result of conditions similar to Flood No. 17, except that it was here assumed that the bottom outlets of Urft Dam would be kept closed as in Flood No. 16. The result of such operation would be that the duration of flow would be reduced several days from that produced by Flood No. 17 as may be seen in Table 9.

(4) Artificial Flood No. 19 involves Type B discharges from all the outlets of Urft and Rur Dams enlarged as described in paragraph 4-04c(2) and (4). The enlarged outlets would increase the discharge at Heimbach to $341 \text{ m}^3/\text{sec}$, but the duration of the wave above $100 \text{ m}^3/\text{sec}$ would be only one day longer than the 9 days computed for Flood No. 15. Flood No. 19 would recede to $30 \text{ m}^3/\text{sec}$ in 16 days, about 8 days sooner than in the case of Flood No. 15, as shown in Table 9. Plate 10 shows the depth, discharge, and velocity of this flood compared to natural flows.

(j) Artificial Flood No. 20 shows the effect of initial pool stage. The pool was assumed to be at $1/2$ full capacity while otherwise conditions were identical to those of Flood No. 19. The initial discharge of Flood No. 20 is $148 \text{ m}^3/\text{sec}$ at Heimbach as compared to $341 \text{ m}^3/\text{sec}$ for Flood No. 19, while the duration of flow is about 5 days less as may be noted in Table 9. Discharge hydrographs of Flood No. 20 at Heimbach and the Maas River appear on Plate 19.

(k) Artificial Flood No. 21 illustrates the possible flow variation that could be affected by means of the Urft Dam outlets in the event that the Rur Reservoir had been previously emptied. A peak discharge of approximately $68 \text{ m}^3/\text{sec}$ would be attained at Heimbach from the combined flow of the normal bottom outlets and power tunnel of Urft Dam. The discharge would be sustained above $30 \text{ m}^3/\text{sec}$ for about 10 days, considerably less than the 21 days from similar opening of Rur Dam alone (See Flood No. 11) and the 24 days of Flood No. 15, involving combined discharges from both the Urft and Rur Dams, as shown in Table 9.

(3) Flow Variations Created by Heimbach and Obermaubach Dams.

(a) Artificial Flood No. 22 represents the flow variation in the Rur River resulting from sudden opening of the weir gate at Heimbach Dam under normal full pool conditions. See Paragraph 4-04c(5) for description of the weir discharge capacity. The peak discharge would be $407 \text{ m}^3/\text{sec}$ at the dam, but the duration of the wave would be only about 2 hours as shown in Table 10. Assuming that the similar dam at Obermaubach was previously opened or destroyed, the peak discharge at the Maas River would be $76 \text{ m}^3/\text{sec}$ and the duration of the wave about 5 hours at the latter location. Plate 20 shows representative discharge hydrographs for this flood.

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(b) Artificial Flood No. 23 shows the effect of synchronized operation of Heimbach and Obermaubach Dams. Assuming that the gate at Obermaubach was held in closed position until arrival of the peak of the wave resulting from opening of the Heimbach weir gate, the peak discharge from Obermaubach Dam would be about 630 m³/sec as shown in Table 10 and on Plate 20. The resulting peak discharge at the Maas River would be 170 m³/sec as contrasted with 76 and 99 m³/sec corresponding respectively to separate operation of the Heimbach and Obermaubach Dams. (See Floods 22 and 25).

(c) Artificial Flood No. 24 shows the effect produced by permitting the wave from Heimbach Dam (Flood No. 22) to be temporarily retained in the initially empty Obermaubach pool and then suddenly released. The peak at Obermaubach would be thus increased from 176 to 304 m³/sec but the resulting peak discharge at the Maas River would be lowered from 76 to 54 m³/sec as compared to the uninterrupted wave of Flood No. 22. The duration of the flow would not be appreciably changed, as shown in Table 10.

(d) Artificial Flood No. 25 is the result of sudden opening of the Obermaubach weir gates and outlet under normal full pool conditions. A peak discharge of 500 m³/sec would emit from the opening but the flow would recede in about 2 hours to the base flow, as shown in Table 10. The peak discharge at the Maas River would be about 99 m³/sec.

(4) Flow variations Created by Kall and Dreilaegerbach Dams.

(a) Artificial Flood No. 26 is the result of sudden full opening of the existing normal outlets of Kall Dam under conditions of full pool. The resulting hydrograph would have a peak of 15 m³/sec and a total duration of about 46 hours, as shown in Table 8 and on Plate 21. The resulting peak flow in the Rur River at Zerkall would be 24 m³/sec, an increase of 14 m³/sec. over the assumed 10 m³/sec initial base flow in the Rur River, thus representing practically no reduction in the peak flow.

(b) Artificial Flood No. 27 is the result of discharge from the outlets of Kall Dam enlarged as indicated in paragraph 4-04(6). The initial peak discharge would be increased from 15 to 44 m³/sec but the reservoir would be emptied in about 18 hours as compared to the 46 hour duration from the unmodified outlets of Flood No. 26. Effects are summarized in Table 8.

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(c) Artificial Flood No. 28 represents the effect of full opening of the existing outlets of Dreilaegerbach Dam at full reservoir stage. The resulting discharge hydrographs are shown on Plate 21. The peak discharge from the dam of $12 \text{ m}^3/\text{sec}$ would be practically undiminished at the confluence of the Inde and Rur Rivers, as indicated on Table 8.

(d) Artificial Flood No. 29 is the result of discharge from the outlets of Dreilaegerbach Dam, enlarged as described in paragraph 4-040(7). Initial peak discharge at the dam would be increased only to $16 \text{ m}^3/\text{sec}$, thus reducing the total duration of the discharge to 92 hours, as compared with the 124 hour duration of Flood No. 28. Effects are summarized in Table 8.

e. Comparison of Effects of Flow Variations.

The comparative peak values and durations of the flow variations produced by discharges from the outlets of the various Rur River dams are summarized in Tables 8, 9, and 10, and the resulting widths of flooding during passage of the peaks are tabulated in Table 11. Extracts of pertinent effects at Juelich from Tables 8 to 11, inclusive, are presented, as follows, to facilitate comparison:

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Comparison of Flow Variations at Juelich (Km 116)

Peak Values						Duration	
Flood No.	Disch. m ³ /sec	Stage m-AM	Mean Surface	Arrival Time Hour	Width Flooded Km	Above 100 m ³ /sec	Above 30 m ³ /sec
			Vol. m/sec			Days	Days
<u>(1) Urft & Rur Dam Flow Variations</u>							
11	78	78.2	1.8	58	0*	0	21
12	67	78.2	1.8	42	0*	0	12
13	225	79.5	2.4	12	0.1	8	12
14	111	78.7	2.1	34	"	3	7
15	111	78.7	2.1	50	"	9	24
16	111	78.7	2.1	50	"	9	21
17	100	78.6	2.1	50	"	1	15
18	100	78.6	2.1	50	"	0	12
19	251	79.6	2.5	12	"	10	16
20	140	78.9	2.2	42	"	6	11
21	65	78.2	1.8	75	0*	0	10
<u>(2) Heinbach & Obermaubach Flow Variations</u>						Hours	Hours
22	128	78.8	2.2	8	0.1	1	4
23	322	80.0	2.6	8	"	3	5
24	114	78.7	2.1	13	"	1	3
25	197	79.3	2.4	5	"	1	3
<u>(3) Kall & Dreilaegerbach Flow Variations</u>						Days	Days
26	23(Est)	-	-	-	0*	-	-
27	34 "	-	-	-	0*	-	-
28	21	77.6	1.2	18	"	6 (total)	
29	25	77.7	1.3	13	"	5 "	

*No apparent flooding; flow probably confined within stream bank

4-05 ARTIFICIAL FLOODING POTENTIALITIES OF CANALS.

The absence in this area of navigation canals or any other large canal system precludes utilization of canals for artificial flooding. The industrial water-supply canals mentioned in paragraph 2-12, would serve to increase the extent of flooded areas resulting from still-water barriers, major flood waves, and flow variations discussed in this section. Insufficient data are available at this time to permit analysis of the extent of such increased flooding.

4-06 SUMMARY.

The artificial flooding potentialities of the Rur River described in preceding paragraphs 4-01 to 4-05 are herein summarized:

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a. Temporary damming operations at suitable bridge openings would create flooding conditions extending 1 to 3 km upstream from these locations with average widths of overbank flooding ranging from 100 to 500 m and depths of 0.4 to 0.8 m. A continuous barrier could not be formed by this means except during periods of high flows. Associated breaching of local levees would also be necessary. Reference is made to paragraph 4-02 for detailed discussion and to Table 6 and Plate 14 for tabular and graphical summation of effects.

b. Breaching of the Urft and Schwammenauel (Rur) Dams would create major artificial flood waves in the Rur River with amplitudes ranging from approximately 4 to 11 m at Zerkall (km 79) and from 2 to 4 m at Stah (km 152). Effects on the Maas River were not analyzed in detail, but based on information in Reference 29, it is estimated that the waves would not exceed 3 m above normal navigation pool stage, assuming that the navigation dams were lowered prior to arrival of the wave. The start of the artificial flood waves would arrive at Zerkall in about 1 to 2 hours and at Stah in 7 to 11 hours. The average rate of rise of stage would vary considerably, ranging from about 1 to 10 m/hr at Zerkall and 0.3 to 4 m/hr at Stah. Mean surface velocities at the crest of the wave would vary from about 3 to 4.5 m/sec at Zerkall but would be only about 1.3 m/sec at Stah. Overbank flooding could be expected to persist for not over 2 days in most locations, and stream velocities in excess of about 1 to 2 m/sec would prevail for 2 to 4 days. Reference is made to paragraph 4-03 for detailed discussion of effects under various conditions and to Table 7 for summation of effects.

c. Breaching of the Kall or Dreilaegerbach Dams would create relatively small and short flood waves. On the Rur River, amplitudes would be less than 2 m and the duration of the wave would be less than 12 hours as shown in Table 8 and described in paragraph 4-03.

d. Detrimental flow variations could be produced in the Rur River ranging in amplitude from approximately 1 to 3.5 m at Zerkall (km 79) and 1.5 to 2 m at Stah (km 152) by manipulation of the controlled outlets of Urft and Schwammenauel (Rur) Dams. It would take about 2 hours for the start of the wave to arrive at Zerkall and from 12 to 15 hours to arrive at Stah. The rate of rise would vary considerably depending on conditions at the dams, and would range from 0.04 to 1.2 m/hr at Zerkall and 0.02 to 0.23 m/hr at Stah. Mean surface velocities during the passage of the crest of the waves would reach as high as about 3 m/sec at Zerkall and 1.2 m/sec at Stah. Overbank flooding could be effected for periods of 3 to 10 days in most locations by combined discharge from the outlets of both the Urft and Schwammenauel Dams. Mean surface velocities in excess of about 1 to 2 m/sec would persist for periods up to nearly 4 weeks. Cyclic variation of flow with amplitudes as high as 2 m could be maintained for an extended period by repeated opening and closing of the outlets. Detailed information is contained in Table 9 and in paragraph 4-04.

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e. Sudden opening or demolition of the weir gates at Weirbach and Obermaubach Dams would produce detrimental flow variations in the Rur River downstream of these structures of 1.8 m amplitude at Zerkall and ranging from 1.5 to 2 m at Stah. As shown in Table 10, synchronized operation of these two structures could appreciably intensify the effects downstream of Obermaubach Dam. The start of the rise would require about 2 hours to travel from Weirbach Dam to Obermaubach Dam and about 10 hours from the latter point to Stah. The average rate of rise of the waves would be nearly 2 m/hr in the reaches between the two structures and range from about 0.5 to nearly 2 m/hr downstream of the Obermaubach Dam. The duration of overbank flooding would be short, only about 1 hour; and the duration of above normal velocities would not exceed 3 to 6 hours. Possibilities of cyclic variation are excellent, due to large volume of water stored in the Urft and Schwarzenau reservoirs. From these sources, the Weirbach pool can be refilled in about 4 hours, and the Obermaubach pool in less than 8 hours. A summary of effects is presented in Table 10 and detailed discussion of possible flow variations is included in paragraph 4-04.

f. Flow variations in the Rur River caused by operation of the Kall and Dreilaegerbach Dam outlets would be slight. Discharge from the existing outlets of Kall Dam would result in a rise of stage in the Rur River at Zerkall of only about 0.3 m, and enlargement of the outlets would only result in about 0.8 m rise at that location. The Dreilaegerbach outlet discharge would not raise the stage at Juelich over 0.2 m, even if enlarged. Stages would recede to normal in 1 to 6 days. Flow from these dams could be utilized to provide water for still-water barriers or to slightly increase the peak or duration of flow variations from the other dams. More detailed information may be found in Table 8 and in paragraph 4-04.

g. The numerous small check dams located approximately one km apart along the Rur River would have little effect upon the artificial flooding effected by dam breaching or outlet discharge, as was observed during the February 1945 Rur River crossings described in Exhibit C. Insufficient data were available to evaluate the possibilities of increasing the height of these dams to create still-water barriers.

h. The amount of flooding to be expected as a result of breaching or regulated discharge depends largely upon the base flow, (i.e. the flow of water existing in the stream prior to the artificial flood or flowing into the reservoirs). Normally most of the flow in the Rur River is comprised of discharge from the Urft and Schwarzenau Dams, and in that event, high base flow would not appreciably increase the amplitude of artificial flood waves,

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but would increase somewhat the rate of travel of the start and peak of the waves, and would increase the duration of the recession of the wave. For example, if an inflow were entering the reservoirs, the duration of overbank flooding for the flow variations designated as Floods 11 to 21 (with an average $10 \text{ m}^3/\text{sec}$ base flow assumed in this report) would be reduced approximately one day and the duration of flows in excess of $30 \text{ m}^3/\text{sec}$ would be reduced approximately 10 to 20 percent.

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SECTION V

EFFECT ON MILITARY OPERATIONS

5-01 GENERAL.

The purpose of this section is to assist military planning personnel in estimating the relative value and effect of artificial floods upon associated military factors such as bridging, ferrying, and trafficability. The effects of artificial floods upon military operations may vary greatly, depending on hydrologic and weather conditions, the tactical and logistical situation, and the type of equipment involved. Reference is made to Section IV for discussion of the hydraulic features associated with artificial flooding.

5-02 CHARACTERISTICS OF MILITARY BRIDGING.

a. The loading capacities of standard U. S. Army floating bridging, for conditions classified as "Safe, Caution, and Risk Crossings," for various current velocities are tabulated in Table 12. Included are the current velocities which are presumed to destroy the bridge in place with no load, the values ranging from 9 to 16 feet per second (i.e. about 2.7 to 4.9 m/sec). Table 12 is primarily based on data contained in References 30 and 31.

b. It should be noted that the velocities shown in Table 12 represent general averages. The ability of floating bridges to withstand current velocities depends upon numerous variable factors, such as special provisions for securing the bridge, the rate of change in river stage, direction and variability of current debris carried by the stream and other considerations. Standard bridging has been successfully utilized under conditions more severe than indicated in Table 12, and has failed under apparently less critical velocity.

5-03 1945 RUR RIVER CROSSING.

a. A detailed account of the difficulties encountered by the American forces during the crossing of the Rur River in February 1945 (presented as Exhibit C of this report) includes description of the effect that the German possession of Urft and Schwanenauel Dams and the destruction of the outlets of those dams by the retreating Germans, had upon the Allied crossing of the Rur River. Information is also contained in References 23 and 25, listed in the Bibliography, as well as in several other documents unlisted for security reasons.

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b. The American forces reached the west side of the Rur River in December 1944. Estimates of the situation emphasized that large-scale crossings of the Rur River below the sites of the Urft and Schwammenauel (Rur) Dams should not be undertaken until those dams were in friendly hands, due to the possibility that the Germans might release artificial flood waves by destruction of the dams or their outlets. Attempts to remove this threat by destruction of the dams by aerial bombing were unsuccessful. Intensive efforts were made to capture those damsites by ground attack prior to attempting crossing of the river.

c. The Ardennes breakthrough by the Germans caused withdrawal of Allied forces from the Rur River line until 5 February 1945. The Urft and Rur damsites were captured on 10 February, but the enemy had blown the outlet gates, which created flooding to a depth of 3 feet over the banks near Dueren. The resulting current velocities were estimated as being 10 to 12 miles per hour, and crossing operations were delayed until the current moderated.

d. The Rur River was successfully crossed by American forces on 23 February, although the current velocities, were still over 8 miles per hour. Considerable difficulties were encountered due to the swift current as well as to enemy resistance. (See Exhibit C). Construction of floating bridges was hindered by the swift current and by the rapid fall in river stage during and after the night of 23-24 February. Reference is made to Exhibit C and to References 23 and 25 for more detailed description of the effect of artificial flooding on the Rur River crossing.

5-04. EFFECT OF STILL-WATER BARRIERS AND DRAINAGE OBSTACLES.

a. Reference is made to paragraphs 4-02 and 4-06 for discussion of the hydraulic features associated with formation and augmentation of water obstacles by means of temporary damming operations or by disruption of normal drainage.

b. Bridging and ferrying operations within the backwater reaches upstream from the temporary dams would be hindered by reason of the resulting greater width and depth of crossing, indicated in Table 6 and on Plate 14. Approach trafficability would be decreased by the shallow overbank flooding, and the increased stream depths would hinder fording of the affected reaches of the river. Since the resulting increased water obstacle would not be continuous along the streams (as illustrated on Plate 14), still-water barriers must be combined with other natural obstacles and with tactical operations in order to channelize military action.

c. Continuous military support of the temporary dam installations would be necessary to prevent their destruction by enemy air or ground action. Destruction of a temporary dam would release a flood wave of short duration that would temporarily hinder

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crossing operations below the structure and which might cause progressive failure of other downstream structures.

d. Breaching of levees would be necessary in some cases while, in others, blocking of culverts and drainage outlets would be required in addition to temporary damming operations in order to create effective still-water barriers and drainage obstacles.

5-05 EFFECT OF MAJOR FLOOD WAVES.

a. Reference is made to paragraphs 4-03 and 4-06 for discussion of the hydraulic features associated with creation of major flood waves by means of breaching of the storage dams located on the Rur River and its tributaries.

b. Breaching of the Urft, Schwammenauel (Rur), Kall or Dreilaegerbach Dams would create artificial flood waves that would destroy or endanger bridges and dams along the streams for an undetermined distance below the breached dam. Insufficient data are available regarding the structural features of existing bridges and dams to permit estimate of the degree of destruction.

c. Breaching of either or both the Urft and Schwammenauel (Rur) Dams would produce temporary flood conditions and high stream velocities which could interfere with stream crossing operations and endanger equipment and floating bridges along the Rur River for several days. See Tables 7 and 11 for summary of resulting flood conditions.

d. Destruction of the Rur River dams would seriously disrupt industrial water supply and electrical power supply of Dueren, Juelich and other important industrial and urban areas.

e. Destruction of the Kall or Dreilaegerbach Dams would seriously disrupt the municipal water supply of the Aachen area.

f. Destruction of the Heimbach or Obermaubach equalizing basins would hinder regulation of industrial water supply for the Dueren-Juelich area.

g. Deliberate demolition of the Rur dams would prevent their use by the enemy in producing detrimental major flood waves or flow variations during a later critical period.

5-06 EFFECT OF FLOW VARIATIONS.

a. Reference is made to paragraphs 4-04 and 4-06 for discussion of the possible detrimental flow variations that could be created in the Rur River by means of regulated discharge from the Rur Dams. The resulting flow conditions are summarized in Tables 8 to 11, inclusive.

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b. Combined or cyclic release of water from the outlets of the Urft and Schwammenauel (Rur) Dam, especially if the outlets are modified to increase the discharge capacity, would produce appreciable flow variations along the Rur River that would endanger floating bridging for considerable distances downstream. The large storage capacities of the reservoirs permit extended durations or multiple repetitions of flow variations. See paragraph 5-03 and Exhibit C for description of observed effects and difficulties encountered during the actual 1945 crossing of the Rur River.

c. Sudden opening of the weir gates of Heimbach and/or Obermaubach Dams would produce appreciable flow variations along the Rur River of short durations that could be repeated for cyclic effect by utilization of water impounded in Urft or Schwammenauel reservoirs.

d. Flow variations induced by release of water from the outlets of Kall or Dreilaegebach Dams would not have a significant effect on floating bridges and crossing operations on the Rur River.

e. Deliberate demolition of the Rur dams or their outlet controls would produce flow variations lasting up to several weeks and prevent use by the enemy in producing major flood waves or detrimental flow variations during a later critical period.

5-07 EFFECTS RELATED TO OTHER BASINS.

Artificial flooding along the Rur River could be coordinated with similar operations on other river basins (especially on the nearby Rhine or Maas Rivers) to create simultaneous or progressive water obstacles affecting military action. Reference is made to reports on studies of artificial flooding possibilities on the Rhine, Danube, Weser, Ems, Ailler and Leine Rivers listed as References 28, 30 and 32 to 35, inclusive, in the Bibliography of this report. Some information regarding artificial flooding possibilities on the Maas (Meuse) River is contained in Reference 29.

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TABLE I
EQUIVALENT ENGLISH-METRIC TERMS

To reduce A to B, multiply A by F. To reduce B to A, multiply B by G.

Unit A	Factor F	Factor G	Unit B
<u>LENGTH</u>			
Miles	1.60935	.62137	Kilometers
Meters	3.2808	.30480	Feet
Meters	39.370	.025400	Inches
<u>AREA</u>			
Square Miles	2.590	.3861	Square kilometers
Square Miles	259.000	.0038610	Hectares
Hectares	2.47104	.40469	Acres
Acres	4046.9	.00024710	Square Meters
<u>VOLUME</u>			
Cubic Meters	35.3145	.028317	Cubic Feet
Cubic Feet	28.317	.035314	Liters
Acro-feet	43560.	.000022957	Cubic Feet
Acro-feet	1233.5	.00081071	Cubic Meters
<u>DISCHARGE</u>			
Cubic feet per second	1.9835	.50417	Acro-feet per 24 hours
Cubic meters per second	35.3145	.028317	Cubic-feet per second
<u>VELOCITY</u>			
Miles per hour	1.60935	.62137	Kilometers per hour
Miles per hour	1.4667	.68182	Feet per second
Meters per second	2.239	.4470	Miles per hour
Meters per second	3.2808	.30480	Feet per second
Meters per second	2.2369	.44704	Miles per hour
Feet per second	1.097	.9113	Kilometers per hour
<u>WEIGHT</u>			
Tons (metric)	1.102	.9072	Tons (short)
Tons (long)	1.016	.9842	Tons (metric)
Tons (metric)	2205.	.0004536	Pounds (avoirdupois)
Tons (metric)	1000.	.001	Kilograms

TABLE 2
HYDROLOGIC TERMS AND ABBREVIATIONS
(As commoned with German practice)

Abbreviation	High-Tide Stage	Low-Tide Stage	Rate of Discharge	Discharge per Unit Area		Definition
	HTW	LWTW	(m^3/sec)	HTW	LWTW	
HTW	HTW	LWTW	HTW	HTW	LWTW	Highest value ever known or observed
HTW	HTW	LWTW	HTW	HTW	LWTW	Highest value observed during a stated period of time
HTW	HTW	LWTW	HTW	HTW	LWTW	The mean high value during a stated period, derived by averaging the highest values of each unit time element (i.e., 1926/35 is average of the 10 yearly peak stages)
HTW	HTW	LWTW	HTW	HTW	LWTW	The mean (arithmetical average) of all observations during a stated time period
HTW	HTW	LWTW	HTW	HTW	LWTW	The mean low value during a stated period, derived by averaging the lowest values of each unit time element (1926/35 is the average of the 10 yearly lowest stages)
HTW	HTW	LWTW	HTW	HTW	LWTW	Lowest value observed during a stated period of time
HTW	HTW	LWTW	HTW	HTW	LWTW	Lowest value ever known or observed

Table 2

TABLE 3
SUMMARY OF DAM DATA

Dam	Urft	Paulshof	Schwammenauel	Heinbach	Obermünzbech	Kall	Dreilaagerbach
River	Urft	Rur	Rur	Rur	Rur	Kall	Inde
Grid Coordinates	068234	045242	083272	110262	090360	990283	922301
Drainage Area (km ²)	375	—	300***	—	794.6	29	11
Year Built	1904	1934-35	1935-37	1933-35	1933-35	1934-36	1909-11
Material	Masonry	Earth	Earth	Masonry	Earth	Earth	Masonry
Storage Cap. (10 ⁶ m ³)	45.5	1.75	100.0	1.25	1.65	2.1	4.3
Height (m)	58	10.5	62	9.0	7.3	39.5	49
Length (m)	226	132	350	170	166	180	240
Width (base) (m)	50.5	—	30	—	—	164	37
Purpose*	(1),(2),(3)	—	(1),(2),(3)	(4)	(4)	(1)	(1)
Mean Annual Power (10 ⁶ kwh)	15	—	16	—	—	—	—
Operating Company**	(a)	(a)	(a)	(a)	(a)	(b)	(b)
Annual outflow (10 ⁶ m ³)	172.0	—	173.0	—	398.0	18.6	34.6

*Purpose: (1) water supply; (2) power generation; (3) flood control; (4) equalizing basin

**Operating Company: (a) Kurtaisperrren-Gesellschaft
(b) Wasserverk d. Landkreis-Aachen
(c) Wasser-Gen. Obermünzbech

***Exclusive of Urft Dam, located upstream of Schwammenauel Dam, on the Urft River,
A branch of the Rur River

Source: Reference 3, 36

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TABLE 4: Description of Bridges
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Location	Kilometer Point	Description	Bridge Length, with Approach (feet)	Spans	Capacity	River Width (feet)	River Depth (feet)	Remarks
1. GONJALIS Sheet II K 91746 K 91747	7.5 Km (4.66 miles)	Single span double track railroad bridge with stone arches.	27.8	1 x 29.37 ft clearance width.		20.7	1.6	AT VITH- ARNEY LINE.
2. KATIBORONG K 91746 K 91747	12 Km (7.45 miles)	2 span road bridge of stone superstructure.	53.7	2 x 13.1 ft clearance width.	15 ton vehicle load. Class II	16.4	1.9	KATIBORONG- KINHELECHAND Rd.
3. KATIBORONG K 91747	12.1 Km (7.53 miles)	Single span double track railroad bridge of stone superstructure.	20.5	1 x 108.2 ft clearance width.		16.4	1.9	KATIBORONG- KINHELECHAND Rd.
4. KATIBORONG K 91746	12.75 Km (7.91 miles)	2 span double track railroad bridge of stone superstructure.	20.5	2 x 42.6 ft 1 x 13.1 ft clearance width.		20.5	1.9	KATIBORONG- KINHELECHAND Rd.
5. KATIBORONG K 91747	13.1 Km (8.25 miles)	Single span double track railroad bridge of stone superstructure.	20.5	1 x 42.6 ft clearance width.		20.5	1.9	KATIBORONG- KINHELECHAND Rd.
6. KATIBORONG K 91746	13.4 Km (8.36 miles)	Single span road bridge with stone superstructure.	35.2	19.6 ft plus 2 sidewalks 1.6 ft ea. clearance width.	10 ton vehicle load. Class II	19.6	1.9	KATIBORONG- KINHELECHAND Rd.
7. BONGSUT K 91747	21.2 Km (13.2 miles)	2 span road bridge of stone superstructure.	49.2	19.6 ft plus 2 sidewalks 1.6 ft ea. clearance width.	10 ton vehicle load. Class II	19.6	1.9	KATIBORONG- KINHELECHAND Rd.
8. North of BONGSUT K 91747	21.5 Km (13.4 miles)	2 span road bridge of steel superstructure.	85.3	14.7	10 ton vehicle load. Class II	14.7	1.9	KATIBORONG- KINHELECHAND Rd.

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TABLE 4: Description of Bridges
SECURED INFORMATION

Location	Kilometer point	Description	Bridge Length (ft.)	Bridge Width (ft.)	Span clearance width.	Capacity	River Width (feet)	River Depth	Remarks
1. FISHKILL	3.5 Km (11.5 mi.)	1 span road bridge with stone arches.	195.2	18	3 @ 24.4 ft clearance width.	24 ton veh- hicle load Class I	65.6	.9	REPAIRS- SCHEDULED IN NEAR FUTURE
2. SOUTH OF FISHKILL	9	9 span road bridge of steel superstructure.	432.9	9.8	9 @ 37.7 ft clearance width.	3 ton veh- hicle load Class IV	911.6	19.6	
3. FISHKILL	45.0 Km (28.1 mi.)	3 span road bridge of reinforced concrete superstructure.	141	9.8 ft plus 4 @ 36.2 ft 2 side walks 1 @ 15.4 ft 2.4 ft. ea. clearance width.	16 ton veh- hicle load Class II	4.33	34.4		
4. FISHKILL	1.0 Km (0.6 mi.)		904	50.5					
5. SOUTH OF FISHKILL		Postbridge.	308	4.9					
6. FISHKILL	54.4 Km (33.8 mi.)	3 span road bridge with stone arches.	176.3	15.7	2 @ 39.3 ft 1 @ 35.9 ft clearance width.	24 ton veh- hicle load Class I	59	1.6	REPAIRS- SCHEDULED FORD.
7. FISHKILL		Ford.							Only to be used when the water is completely retained by HUR dam.

TABLE 4: Description of Bridges

RESTRICTED

SECTION

Line No.	Location	Span Length (ft)	Description	Bridge Length (ft)	Span Width (ft)	Spans	Capacity	River Width (ft)	Remarks
15	BRIDGE P 112.08	70.8 ft (41.02 miles)	1 span road bridge with stone arches	70.8	15.7 ft plus 2 sidewalks 3.2 ft ea.	1 span 30.8 ft clearance width	24 ton vehicle load Class I	65.6	1.6
16	BRIDGE P 112.08	70.8 ft (41.02 miles)	1 span road bridge with stone arches	70.8	15.7 ft plus 2 sidewalks 3.2 ft ea.	1 span 30.8 ft clearance width	24 ton vehicle load Class I	65.6	1.6
17	BRIDGE P 112.08	70.8 ft (41.02 miles)	1 span road bridge with stone arches	70.8	15.7 ft plus 2 sidewalks 3.2 ft ea.	1 span 30.8 ft clearance width	24 ton vehicle load Class I	65.6	1.6
18	BRIDGE P 112.08	70.8 ft (41.02 miles)	1 span road bridge with stone arches	70.8	15.7 ft plus 2 sidewalks 3.2 ft ea.	1 span 30.8 ft clearance width	24 ton vehicle load Class I	65.6	1.6
19	BRIDGE P 112.08	70.8 ft (41.02 miles)	1 span road bridge with stone arches	70.8	15.7 ft plus 2 sidewalks 3.2 ft ea.	1 span 30.8 ft clearance width	24 ton vehicle load Class I	65.6	1.6
20	BRIDGE P 112.08	70.8 ft (41.02 miles)	1 span road bridge with stone arches	70.8	15.7 ft plus 2 sidewalks 3.2 ft ea.	1 span 30.8 ft clearance width	24 ton vehicle load Class I	65.6	1.6
21	BRIDGE P 112.08	70.8 ft (41.02 miles)	1 span road bridge with stone arches	70.8	15.7 ft plus 2 sidewalks 3.2 ft ea.	1 span 30.8 ft clearance width	24 ton vehicle load Class I	65.6	1.6
22	BRIDGE P 112.08	70.8 ft (41.02 miles)	1 span road bridge with stone arches	70.8	15.7 ft plus 2 sidewalks 3.2 ft ea.	1 span 30.8 ft clearance width	24 ton vehicle load Class I	65.6	1.6
23	BRIDGE P 112.08	70.8 ft (41.02 miles)	1 span road bridge with stone arches	70.8	15.7 ft plus 2 sidewalks 3.2 ft ea.	1 span 30.8 ft clearance width	24 ton vehicle load Class I	65.6	1.6
24	BRIDGE P 112.08	70.8 ft (41.02 miles)	1 span road bridge with stone arches	70.8	15.7 ft plus 2 sidewalks 3.2 ft ea.	1 span 30.8 ft clearance width	24 ton vehicle load Class I	65.6	1.6

In use only when value is completely retained by bar den.

Only to be used when value is completely retained by bar den.

Reproduced from: Detailed Description of Crossings over the Hoor (Rur) and Niers Rivers and the Niers Mass Canal, Hq. ETOUSA, GCE (Int. Div.), Nov. 1944.

Table 4: Description of Bridges
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 SECURITY INFORMATION

Serial No.	Location	Elevation Point	Description	Bridge Length (feet)	Bridge Width (feet)	Spans	Capacity	Water Depth (feet)	River
24	UTTER LANE P 000773	86.84 M (53.1 miles)	4 span road bridge with stone arches.	216	15.0 ft plus 2 sidewalks 1.6 & 2.6 ft.	4 x 44.2 ft clearance width.	14 ton vehicle load.	158.4	13
25	UTTER LANE P 112772	87.1 M (54.0 miles)	3 span road bridge with stone arches.	206	7.2 ft plus 2 sidewalks 2.1 & 3 ft.	1 x 53.8 ft clearance width.	7 ton vehicle load.	93.2	1.6
26	UTTER LANE P 115770	89.1 M (55.4 miles)	5 span road bridge with stone arches.	242.7	18.7 ft plus 2 sidewalks 3.1 ft ea.	5 x 37.5 ft clearance width.	24 ton vehicle load.	62	1.3
27	UTTER LANE P 117121	90.8 M (56.5 miles)	4 span road bridge with stone arches.	246.4	15 ft plus 2 sidewalks 3.7 ft ea.	4 x 43.3 ft clearance width.	24 ton vehicle load.	137	1.1
28	UTTER LANE P 113444	95.2 M (59.2 miles)	5 span road bridge with stone arches.	229.5	21.5 ft plus 2 sidewalks 7.8 ft ea.	5 x 30 ft clearance width.	24 ton vehicle load.	131	1.0
29	UTTER LANE P 107452	96.5 M (60.0 miles)	2 span double track railroad bridge with steel truss superstructure.	295.2	32	2 x 127.5 ft clearance width.	24 ton vehicle load.	131	1.0
30	UTTER LANE P 104256	96.7 M (60.1 miles)	2 span double track railroad bridge with steel truss superstructure.	295.2	32	2 x 127.5 ft clearance width.	24 ton vehicle load.	131	1.0
31	UTTER LANE P 104256	98.2 M (61.1 miles)	3 span single track railroad bridge.	309.4	15	3 x 103.2 ft clearance width.	18 ton vehicle load.	131	1.0

Reproduced from: "Detailed Description of Crossings over Erie Canal (Part) and
 Yates Rivers and the Erie-Wash Canal," No. 5718, CE (1924, Nov.), Nov. 1924.

RESTRICTED

TABLE 4: Description of Bridges RESTRICTED
SECURITY INFORMATION

Bridge No.	Location	Structure	Span Length (ft.)	Bridge Width (ft.)	Spans	Capacity	River Width (ft.)	River Depth (ft.)	Remarks
1	2 x 24.6 ft. clearances	24 ton veh. bridge load. Class I	65.6	1.9	...
2	3 openings. Class IV	...	65.6
3	2 x 11.7 ft. clearances	7 ton veh. bridge load. Class III	65.6	2.3	...
4	6 x 16.2 ft. clearances	20 ton veh. bridge load. Class G	76.7	8.2	...
5	...	Private Bridge
6	20.3 ft. clearances	24 ton veh. bridge load. Class I	59	2.6	...
7	7 openings	7 ton veh. bridge load. Class III	65.6	2.6	...
8	2 x 11.7 ft. clearances	24 ton veh. bridge load. Class I	65.6	2.6	...
9	2 x 11.7 ft. clearances	24 ton veh. bridge load. Class I	75.4	2.4	...

RESTRICTED

TABLE 4: Description of Bridges

AND (OR) RIVER

Order	Location	Spanner	Description	Bridge Length (ft.)	Bridge Width (ft.)	Notes
-------	----------	---------	-------------	------------------------	-----------------------	-------

19 North of
STINKING
A. 2220

20 Road bridge.

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TABLE 5

SUMMARY OF GAGE DATA - RUM (ROER) RIVER

Gaging Station	River Km	Gage Zero	Drainage Area	Period	HW HQ HQ cm m ³ /s 1/s/km ²	MW MQ MQ cm m ³ /s 1/s/km ²	NW NQ NQ cm m ³ /s 1/s/km ²	SW SQ SQ cm m ³ /s 1/s/km ²	WW WQ WQ cm m ³ /s 1/s/km ²	N D J F M A M J J A S O											
	Km	m + mm	Km ²																		
ZINKHALL	78.2	171.13	767.1	1937	7	12	44	188	(1)400	Mean Monthly Gage Heights (cm.)											
				to						43	56	58	69	59	62	39	29	29	29	31	
				1940	1.0 1.3	1.5 1.9	12.8 16.2	95 120	280 355	Mean Monthly Discharge (m ³ /s)											
JUELICH	115.2	76.96	1344	1937	0	14	47	183	(2)278	Mean Monthly Gage Heights (cm.)											
				to						46	58	61	79	62	66	40	28	26	31	35	34
				1940		1.5 1.1	13.6 10.1	130 97	280 209	Mean Monthly Discharge (m ³ /s)											
STAN	150.5	30.07	2066	1937	28	45	110	298	(3)328	Mean Monthly Gage Heights (cm.)											
				to						104	138	151	185	161	159	101	71	64	65	69	67
				1940	5.0 2.4	8.0 3.9	19.2 9.3	150 72	500 241	Mean Monthly Discharge (m ³ /s)											
										17.5	23.5	26.5	35.0	28.5	28.0	16.5	11.5	10.5	10.5	11.5	11.0

NOTES:

*Average mean monthly discharge

(1)12 January 1920

(2)12 January 1920

(3)31 December 1925

Stage data from "Reference 18-20;" "Q" and "q" values obtained by application of discharge rating curves, Plate 13.

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TABLE 6
RHE (RHE) RIVER
INUNDATION EFFECT OF STILLWATER BARRIERS

Serial No.	USGS Map Series	"Word de Guerre" Grid	River Km	Location and Description*	Dimensions of Inundated Areas											
					Barrier Height (m-m)						Max. Effective Barrier					
					Pond Level mNN	Pond Length km	Pond Width** m	Pond Depth** m	Pond Area km ²	Pond Vol. 10 ⁶ m ³	Pond Level mNN	Pond Length km	Pond Width** m	Pond Depth** m	Pond Area km ²	Pond Vol. 10 ⁶ m ³
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
---	5204 S1	F100374	85.3	Untermuhbach 5 span stone arch Total opening 91.7 m Stream width 30 m	151	1.4	200	0.4	0.33	0.13						
24	5204 S1	F049373	85.6	Untermuhbach Hwy. Bridge 4 span stone arch Total opening 75 m Stream width 36 m	155						157	0.3	100	0.8	0.03	0.024
											Requires blocking to crest of arch. Elev. 155.6 mNN. 157 mNN is roadway elevation.					
25	5204 S1	F112372	87.1	Udingen Hwy. Bridge 3 span stone arch Total opening 63 m Stream width 14.7 m	153.2	1.5	100	0.5	0.21	0.1						
26	5204 S1	F115389	89.3	Kreuzau Hwy. Bridge 5 span stone arch Total opening 74 m Stream width 25 m	145	-	-	-	-	-	147	1.0	240	0.4	.24	0.09
											Pool elev. determined by minimum elev. of embankment.					
27-30			89.3-98.4	Sites not suitable												
31	5104 R1	F100468	98.4	Weleschau RR Bridge 5 spans Total opening 92.5 m Stream width 50 m	118.2	1.0	200	0.5	0.2	0.1						
											Flooding probably confined to gravel bed on left bank.					
32	5104 R1	F094486	100.4	Hirzendorf Hwy. Bridge							No significant flooding					
---	5104 R1	F091406	101.4	Autobahn Bridge 3 span Total opening 124 m Stream width 35 m	110.6	1.0	100	1.5	0.1	0.05						
											Mostly confined to channel except immediately above site.					
33-34			107.9-111.0	Sites not suitable												
35-36	5004 R1	F030572	113.2	South of Juelich RR Bridge 6 span steel truss Total opening 113 m Stream width 35 m	87.5	0.8	150	0.7	0.12	0.004						
											Flooding mainly on right bank.					

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Table 6
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*See Bridge Table for details
*Average width and depth of inundation

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TABLE 6
RUE (ROER) RIVER
INUNDATION AFFECT OF STILL-WATER BARRIERS

OSOS					Dimensions of Inundated Areas											
Serial No.	Map Series	"Lard de Guerre" Grid	River Km	Location and Description*	Barrier Height (Cm)						Max. Effective Barrier					
					Pond Level	Pond Length	Pond Width**	Pond Depth**	Pond Area	Pond Vol.	Pond Level	Pond Length	Pond Width**	Pond Depth**	Pond Area	Pond Vol.
					m	km	m	m	km ²	10 ⁶ m ³	m	km	m	m	km ²	10 ⁶ m ³
37	5004 R1	P027588	114.8	Juelich Hwy. Bridge 3 span stone arch Total opening 103 m Stream width 20 m	6.2	1.6	500	0.8	0.8	0.64	12	13	14	15	16	17
114.8-132.6 Sites Not Suitable																
43	4903 R1	K961703	132.6	Baal RR Br. 6 span masonry Total opening 105 m Stream Width 24 m	55	1.7	600	0.5	1.0	0.5						
47	4902 R1	K807775	146	Orsbeck Hwy. Br. 6 span Total opening 117 m. Stream width 20 m	27.8	2.3	600	0.6	1.38	0.89						
-	4802 R1	K843830	160.5	Vloedrop Hwy. Br.	No significant flooding.											
-	4802 R1	K790847	160.5	Welick Hwy. Br.	No significant flooding.											

*See Bridge Table for details
**Average width and depth of inundation

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Table 6
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SUMMARY OF EFFECTS OF MAJOR FLOOD WAVES
URFT & SCHWAMMENAU (RUR) DAM BREACHES

Location	Rur River km	Artificial Flood No.	Type of Outflow		Initial Conditions		Values at Peak of Wave			Time of Arrival		Duration of Wave	
			Urft Dam	Rur Dam	Pool Storage Level	Base Flow m ³ /sec	Discharge m ³ /sec	Stage m	Mean Surface Velocity m/sec	Start of Wave Hour	Peak of Wave Hour	Above 100m ³ /sec Days	Above 30m ³ /sec Days
Urft Dam	45	1	Breach I	Spillway	Full	5	8500	—	—	0	0	0.5	1.0
Rur Dam	60				Full	10	1250	—	—	0	2	1.5	3.5
Zerkall	79				—	"	1085	177.7	3.5	1	4	"	"
Juelich	116				—	"	960	81.6	2.9	4	8	"	"
Stah	152				—	"	740	33.5	1.3	9	15	"	"
Muse R.	181				—	"	600	16.0	—	16	22	"	4.0
Urft Dam	45	2	Breach II	Spillway	Full	5	1000	—	—	0	0	0.5	1.0
Rur Dam	60				Full	10	360	—	—	0	3	1.5	3.5
Zerkall	79				—	"	330	175.4	3.0	2	6	"	"
Juelich	116				—	"	284	79.8	2.6	5	12	"	"
Stah	152				—	"	252	33.3	1.2	11	18	"	"
Muse R.	181				—	"	224	14.1	—	17	26	"	"
Urft Dam	45	3	—	Breach I	—	—	—	—	—	—	—	—	—
Rur Dam	60				Full	10	8500	—	—	0	0	1.0	1.5
Zerkall	79				—	"	5260	162.4	4.3	1	2	"	"
Juelich	116				—	"	3610	82.8	3.1	3	5	"	"
Stah	152				—	"	2660	35.1	1.3	7	10	"	"
Muse R.	181				—	"	2000	19.4	—	13	18	"	"
Urft Dam	45	4	—	Breach I	—	—	—	—	—	—	—	—	—
Rur Dam	60				1/2 Full	10	1100	—	—	0	0	1.0	1.5
Zerkall	79				—	"	745	176.9	3.3	1	3	"	"
Juelich	116				—	"	580	81.7	2.8	4	8	"	"
Stah	152				—	"	465	33.4	1.2	9	14	"	"
Muse R.	181				—	"	375	15.0	—	17	22	"	"
Urft Dam	45	5	—	Breach II	—	—	—	—	—	—	—	—	—
Rur Dam	60				Full	10	1000	—	—	0	0	1.0	3.0
Zerkall	79				—	"	700	176.8	3.3	1	3	1.5	"
Juelich	116				—	"	560	81.0	2.8	4	9	"	"
Stah	152				—	"	465	33.4	1.2	10	15	"	3.5
Muse R.	181				—	"	375	15.1	—	17	23	"	"

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SUMMARY OF EFFECTS OF MAJOR FLOOD WAVES
UPPER & SCHWABENHAUSEN (BUR) DAM PROJECTS

1 Location	2 River km	3 Artificial Flood No.	4 Type of Outflow		5 Initial Conditions		6 Values at Peak of Wave			7 Time of Arrival		8 Duration of Wave	
			Upst Dam	Bur Dam	Pool Storage Level	Base Flow m ³ /sec	Discharge m ³ /sec	Stage m/ft	Mean Surface Velocity m ³ /sec	Start of Wave Hour	Peak of Wave Hour	Above 100m ³ /sec Days	Above 300m ³ /sec Days
Urft Dam	45	6	Breach 1	Breach 1	Full	5	8500	--	--	0	0	--	--
Bur Dam	60		(Simultaneous)		Full	10	6500	--	--	0	0	2.0	3.0
Zerkall	79				--	"	5510	182.6	4.3	1	2	"	"
Juelich	116				--	"	4000	82.8	3.1	3	5	"	"
Stah	152				--	"	2850	35.1	1.3	7	10	2.5	"
Muse R.	181				--	"	2180	19.5	--	13	18	2.5	3.5
Urft Dam	45	7	Breach 1	Breach 1	Full	5	1350	--	--	0	0	--	--
Bur Dam	60		(Simultaneous)		Full	10	1130	--	--	0	0.5	1.5	2.5
Zerkall	79				--	"	920	177.3	3.4	1	4	"	3.0
Juelich	116				--	"	755	81.3	2.9	4	9	"	"
Stah	152				--	"	635	33.5	1.3	9	15	"	"
Muse R.	181				--	"	535	15.5	--	16	23	"	"
Urft D.	45	8	Breach 1	(Previously	Full	5	8500	--	--	0	0	--	--
Bur Dam	60			breached	Part Full	10	540	--	--	0	3	1.0	2.0
Zerkall	79			by Breach 1	--	"	480	176.1	3.2	2	5	"	2.5
Juelich	116			to give	--	"	400	80.4	2.7	5	11	"	"
Stah	152			Flood 3)	--	"	352	33.3	1.2	10	17	1.5	"
Muse R.	181				--	"	306	14.6	--	17	25	"	"

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TABLE 8

SUMMARY OF EFFECTS OF MAJOR FLOOD WAVES A FLOW VARIATIONS
FALL - DREILAEGERBACH DAM

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Location	7m below Dam	Artificial Flood No.	Type of Outflow	Initial Conditions Pool Storage Level	Base Flow m ³ /sec	Discharge m ³ /sec	Stage m/NW	Mean Surface Velocity m/sec	Time of Arrival Start of Wave Hours	75% of Peak Hours	Peak of Wave Hours	Above 100m ³ /sec Hours	Above 30m ³ /sec Hours	Total Hours
Major Flood Waves by Dam Breaches														
Kall Dam														
Fall Dam	0	9	Breach II	Full	0	1000	--	--	0	0	0	1	2	--
Mur R. (Zerkall)	15			--	10	700	175.2	3.0	1	--	2	2	3	--
Juelich	52			--	"	170	79.1	2.3	2	--	4	5	6	--
Dreilaegerbach Dam														
Dreilaegerbach Dam	0	10	Breach II	Full	0	1000	--	--	0	0	0	2	4	--
Mur R. (Juelich)	37			--	10	222	79.5	2.4	9	--	11	3	5	--
Stan	73			--	"	146	33.1	1.2	11	--	15	7	10	--
Flow Variations by Outlet Discharges														
Kall Dam														
Fall Dam	0		Type A	Full	0	15	--	--	0	0	0	--	--	46
Mur R. (Zerkall)	15	26	(Normal Outlets)	--	10	24	171.8	1.7	2	6	12	--	--	55
Kall Dam														
Fall Dam	0		Type B	Full	0	37	--	--	0	0	0	--	--	18
Mur R. (Zerkall)	15	27	(Enlarged Outlets)	--	10	44	172.3	2.1	2	6	12	--	--	26
Dreilaegerbach Dam														
Dreilaegerbach Dam	0		Type A	Full	0	12	--	--	0	0	0	--	--	124
Mur R. (Juelich)	37	28	(Normal Outlets)	--	10	21	77.6	1.2	9	18	42	--	--	150
Juelichbach Dam														
Juelichbach Dam	0		Type B	Full	0	16	--	--	0	0	0	--	--	92
Mur R. (Juelich)	37	29	(Enlarged Outlets)	--	10	25	77.7	1.3	9	13	36	--	--	118

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TABLE 9
SUMMARY OF RESPONSE TO FLOOD VARIATIONS
TEXT & SIMULATED (SUR) DAMS

Location	Rur River Yr	Artificial Flood No.	Type of Outflow		Pool Storage Level	Initial Conditions		Values of Peak of Wave		Time of Arrival		Duration of Wave	
			Urft Dam	Rur Dam		Base Flow	Discharge	Stage	Weir Surface Velocity	Start of Wave Hour	Peak of Wave Hour	Above 100 m/sec	Above 30 m/sec
Urft Dam	45	11	--	Type A	--	--	--	--	--	--	--	--	--
Rur Dam	60		(Normal	Full	10	80	--	--	0	0	0	21	
Zerkall	79		Bottom	--	"	78	172.8	2.2	2	25	"	"	
Juelich	116		(Outlets)	--	"	78	78.2	1.8	7	58	"	"	
Stah	152		--	--	"	77	72.8	1.2	14	87	"	"	
Mass R.	181	--	--	"	76	12.6	--	22	62	"	"		
Urft Dam	45	12	--	Type A	--	--	--	--	--	--	--	--	--
Rur Dam	60		(Normal	Full	10	70	--	--	0	0	0	12	
Zerkall	79		Bottom	--	"	68	172.6	2.2	2	18	"	"	
Juelich	116		(Outlets)	--	"	67	74.2	1.8	7	42	"	"	
Stah	152		--	--	"	66	72.7	1.2	15	62	"	"	
Mass R.	181	--	--	"	64	12.4	--	23	74	"	"		
Urft Dam	45	13	--	Type B	--	--	--	--	--	--	--	--	--
Rur Dam	60		(Enlarged	Full	10	304	--	--	0	0	0	12	
Zerkall	79		Bottom	--	"	251	174.8	2.9	2	6	"	"	
Juelich	116		Outlets	--	"	224	79.5	2.4	6	12	"	"	
Stah	152		= opened	--	"	210	73.2	1.2	12	21	"	"	
Mass R.	181	Weir Gate)	--	"	195	13.5	--	15	29	"	"		
Urft Dam	45	14	--	Type B	--	--	--	--	--	--	--	--	--
Rur Dam	60		(Enlarged	Full	10	117	--	--	0	0	4	7	
Zerkall	79		Bottom	--	"	114	173.2	2.5	2	14	3	"	
Juelich	116		(Outlets)	--	"	111	78.7	2.1	7	34	"	"	
Stah	152		--	--	"	109	73.0	1.2	13	42	"	"	
Mass R.	181	--	--	"	107	13.0	--	21	64	"	8		
Urft Dam	45	15	Type A-1	Type A-	Full	5	30/24	--	--	0	0	--	--
Rur Dam	60		(Normal	(Normal	Full	5	80	--	--	0	0	--	--
Heinbach	61		Bottom	Bottom	--	10	114	--	--	0	0	9	24
Zerkall	79		Outlets	Outlets)	--	"	112	173.4	2.5	2	21	"	"
Juelich	116		& Power	--	"	"	111	78.7	2.1	7	50	"	"
Stah	152	Tunnel)	--	"	"	110	73.0	1.2	13	72	"	"	
Mass R.	181	--	--	"	"	109	13.0	--	21	84	0	"	

* 1st Figure is discharge from Urft Dam bottom outlets into Rur Reservoir. 2nd Figure is discharge from Urft Dam through the power tunnel to Heinbach Power Plant

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TABLE 9
SUMMARY OF EFFECTS OF FLOW VARIATIONS
URFT & SCHWAMMENAGEL (RUR) DAMS

1 Location	2 Rur River Km	3 Artificial Flood No.	4 Type of Outflow		6 Initial Conditions		8 Values of Peak of Wave			11 Time of Arrival		13 Duration of Wave	
			Urft Dam	Rur Dam	Pool Storage Level	Base Flow m ³ /sec	Discharge m ³ /sec	Stage m	Mean Surface Velocity m/sec	Start of Wave Hour	Peak of Wave Hour	Above 100 m ³ /sec Days	Above 30 m ³ /sec Days
Urft Dam	64	16	Type A-2	Type A	Full	5	0/34*	--	--	0	0	--	--
Rur Dam	60		(Normal	(Normal	Full	5	80	--	--	0	0	--	--
Heimbach	61		Power	Bottom	--	10	114	--	--	0	0	10	20
Zerkall	79		Tunnel)	(Outlets)	--	"	112	173.3	2.5	2	21	9	21
Juelich	116				--	"	111	78.7	2.1	7	50	"	"
Stah	152				--	"	110	33.0	1.2	13	72	"	"
Wass R.	181				--	"	109	13.0	--	21	84	"	"
Urft Dam	45	17	Type A-1	Type A	Full	5	27/32*	--	--	0	0	--	--
Rur Dam	60		(Normal	(Normal	Full	5	70	--	--	0	0	--	--
Heimbach	61		Bottom	Bottom	--	10	102	--	--	0	0	2	15
Zerkall	79		Outlets	Outlets)	--	"	101	173.1	2.4	2	21	1	"
Juelich	116		& Power		--	"	100	78.6	2.1	7	50	"	"
Stah	152		Tunnel)		--	"	99	32.9	1.2	14	72	"	"
Wass R.	181				--	"	98	12.8	--	22	84	"	16
Urft Dam	45	18	Type A-2	Type A	Full	5	0/32*	--	--	0	0	--	--
Rur Dam	60		(Normal	(Normal	Full	5	70	--	--	0	0	--	--
Heimbach	61		Power	Bottom	--	10	102	--	--	0	0	1	12
Zerkall	79		Tunnel)	Outlets)	--	"	101	173.1	2.4	2	21	1	"
Juelich	116				--	"	100	78.6	2.1	7	50	0	"
Stah	152				--	"	99	32.9	1.2	14	72	0	"
Wass R.	181				--	"	98	12.8	--	22	84	0	"
Urft Dam	45	19	Type B	Type B	Full	5	44/36*	--	--	0	0	--	--
Rur Dam	60		(Enlarged	(Enlarged	Full	5	305	--	--	0	0	--	--
Heimbach	61		Bottom	Bottom	--	10	341	--	--	0	0	10	16
Zerkall	79		Outlets	Outlets	--	"	280	175.0	3.0	2	6	"	"
Juelich	116		& Power	& Opened	--	"	251	79.6	2.5	5	17	"	"
Stah	152		Tunnel)	Weir Gate)	--	"	234	33.3	1.2	11	20	"	"
Wass R.	181				--	"	218	14.0	--	18	28	"	"

* 1st Figure is discharge from Urft Dam bottom outlets into Rur Reservoir; 2nd Figure is discharge from Urft Dam through the power tunnel to Heimbach Power Plant

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TABLE 9
SUMMARY OF EFFECTS OF FLOW VARIATIONS
URFT & SCHWAMMNAUEL (RUR) DAMS

1 Location	2 Rur River Km	3 Artificial Flood No.	4 Type of Outflow		6 Initial Conditions		8 Values of Peak of Wave			11 Time of Arrival		13 Duration of Wave	
			URFT Dam	Rur Dam	Pool Storage Level	Base Flow m ³ /sec	Discharge m ³ /sec	Stage m-HH	Mean Surface Velocity m ² /sec	Start of Wave Hour	Peak of Wave Hour	Above 100 m ³ /sec Days	Above 30 m ³ /sec Days
Urft Dam	45	20	Type B	Type B	Full	5	79/31*	—	—	0	0	—	—
Rur Dam	60		(Enlarged	(Enlarged	Full	5	117	—	—	0	0	—	—
Heinbach	61		Bottom	Bottom	—	10	148	—	—	0	0	6	11
Zerkall	79		Outlets	Outlets	—	"	144	173.7	2.6	2	18	"	"
Juelich	116		& Power	& Opened	—	"	140	78.9	2.2	6	42	"	"
Stah	152		Tunnel)	Weir Gate)	—	"	138	33.1	1.2	12	62	"	"
Mess R.	181				—	"	126	13.3	—	21	74	"	"
Urft Dam	45	21	Type A-1	Type A	Full	5	70/34*	—	—	0	0	—	—
Rur Dam	60		(Normal	(Normal	Empty	5	34	—	—	0	24	—	—
Heinbach	61		Bottom	Bottom	—	10	68	—	—	0	24	0	10
Zerkall	79		Outlets	Outlets)	—	"	67	172.6	2.2	2	53	"	"
Juelich	116		& Power		—	"	65	78.2	1.8	8	75	"	"
Stah	152		Tunnel)		—	"	65	32.7	1.2	15	87	"	"
Mess R.	181				—	"	64	12.4	—	23	97	"	"

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* 1st Figure is discharge from Urft Dam bottom outlets into Rur Reservoir; 2nd Figure is discharge from Urft Dam through the power tunnel to Heinbach Power Plant

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TABLE 10
SUMMARY OF EFFECTS OF FLOOD VARIATIONS
HEIMBACH & OBERMAUBACH DAMS

1	2	3	4		5	6		7	8		9	10	11		12	13		14
Location	Rur River Km	Artificial Flood No.	Type of Outflow		Initial Conditions		Values at Peak of Wave				Time of Arrival		Duration of Wave					
			Heimbach	Obermaubach	Pool Storage Level	Base Flow	Discharge	Stage	Mean Surface Velocity	Start of Wave	Peak of Wave	Above 100 m ³ /sec	Above 30 m ³ /sec					
														m ³ /sec	m ³ /sec	m	m/sec	Hour
Heimbach Dam	63	22	Gate	Gate	Full	10	407	—	—	—	—	0	0	1	2			
Zerkall	79		suddenly	previously	—	"	195	174.3	2.8	1	2	1	2	1	3			
Obermaubach Dam	84		opened	opened or	Empty	"	176	—	—	2	3	1	3	1	3			
Juelich	116			destroyed	—	"	128	78.8	2.2	6	8	1	4	1	4			
Stah	152				—	"	94	32.9	1.2	12	16	0	4		4			
Mass R.	181				—	"	76	12.6	—	21	24	0	5		5			
Heimbach Dam	63	23	Gate	Gate suddenly	Full	10	407	—	—	0	0	1	2		2			
Zerkall	79		suddenly	opened at	—	"	195	174.3	2.8	1	2	1	3		3			
Obermaubach Dam	84		opened	arrival of	Full	"	176/630	—	—	2	3	1/2	3/4		3/4			
Juelich	116			crest of wave	—	"	322	80.0	2.6	6	8	3	5		5			
Stah	152				—	"	224	33.3	1.3	12	14	4	6		6			
Mass R.	181				—	"	170	13.7	—	19	22	6	9		9			
Heimbach Dam	63	24	Gate	Gate suddenly	Full	10	407	—	—	0	0	1	2		2			
Zerkall	79		suddenly	opened at	—	"	195	174.3	2.8	1	2	1	3		3			
Obermaubach Dam	84		opened	hour 8	Empty	"	176/304	—	—	2/8	3/8	1/1	3/2		3/2			
Juelich	116				—	"	114	78.7	2.1	12	13	1	3		3			
Stah	152				—	"	64	32.7	1.2	19	21	0	5		5			
Mass R.	181				—	"	54	12.2	—	27	30	0	6		6			
Obermaubach Dam	84	25	—	Gate suddenly	Full	10	500	—	—	0	0	1	2		2			
Juelich	116			opened	—	"	197	79.3	2.4	3	5	1	3		3			
Stah	152				—	"	118	33.0	1.3	9	10	1	3		3			
Mass R.	181				—	"	99	12.9	—	17	18	0	5		5			

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Table 10
Page 1 of 1 page

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TABLE 11

ESTIMATED WIDTHS OF FLOODING DUE TO ARTIFICIAL FLOODS (KM)

Location	River Km	ARTIFICIAL FLOOD NO.																																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29						
Zerkall Gage	78.8	0.1	0.1	0.1	0.1		0.1	0.1	0.1	0.1	—	0*		0.1	0.1						0.1	0*	0.1	0.1	0.1	—	0*	0*	—	—						
	94.3	1.5	1.0	2.7	1.7		2.0	1.2	0.9	0.7	—	0.1		0.7	0.5						0.6	0*	0.6	0.8	0.6	0.5	0*	0*	—	—						
	103.9	3.0	2.8	3.4	3.0	Approximately same as Flood #1	3.4	3.4	2.0	2.5	—	1.8	Approximately same as Flood #11	2.5	2.7	Approximately same as Flood #14	Approximately same as Flood #14	Approximately same as Flood #14	Approximately same as Flood #14	Approximately same as Flood #14	2.7	1.7	2.7	2.8	2.7	2.7	0*	0*	—	—						
	108.3	5.7	3.6	7.7	5.8		7.7	7.7	3.8	3.6	—	2.2		3.6	2.2						1.2	0*	3.6	3.8	3.6	3.6	0*	0*	—	—						
Juelich Gage	115.2	0.9	0.1	1.8	0.5		1.8	0.9	0.3	0.1	0.1	0*		0.1	0.1						0.1	0*	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0*	0*	0*	0*	0*	0*
	121.1	1.7	0.1	1.7	1.4		1.7	1.4	0.8	0.1	0.6	0.1		0.5	0.1						0.1	0*	0.1	0.1	0.5	0.1	0.1	0*	0*	0*	0*	0*	0*	0*	0*	0*
	132.6	2.7	0.1	2.8	2.6	2.8	0.1	0.1	0.1	0.1	0*	0.1	0.1	0.1	0*	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0*	0*	0*	0*	0*	0*							
	141.1	0.5	0.3	2.1	0.4	2.1	0.4	0.3	0.1	0.3	0*	0.3	0.1	0.1	0*	0.1	0.1	0.3	0.1	0.3	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*						
Orabock	149.0	1.7	1.4	2.4	1.7	Approximately same as Flood #1	2.4	1.4	1.4	0.1	0.6	0.1	1.4	0.4	Approximately same as Flood #11	Approximately same as Flood #14	Approximately same as Flood #14	Approximately same as Flood #14	Approximately same as Flood #14	Approximately same as Flood #14	0.3	0*	0.4	1.4	0.3	0.4	0*	0*	0*	0*	0*					
	165.0	0.8	0.4	1.5	—		1.7	1.0	0.6	0*	0*	0*	0.4	0*							0*	0*	0.4	0*	0*	0.4	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*
	170.0	0*	0*	1.1	0*		1.7	0*	0*	0*	0*	0*	0*	0*							0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*
	175.0	0*	0*	0.4	0*		0.7	0*	0*	0*	0*	0*	0*	0*							0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*

*No apparent flooding; flow probably confined within stream banks.

Table 11

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Table 11

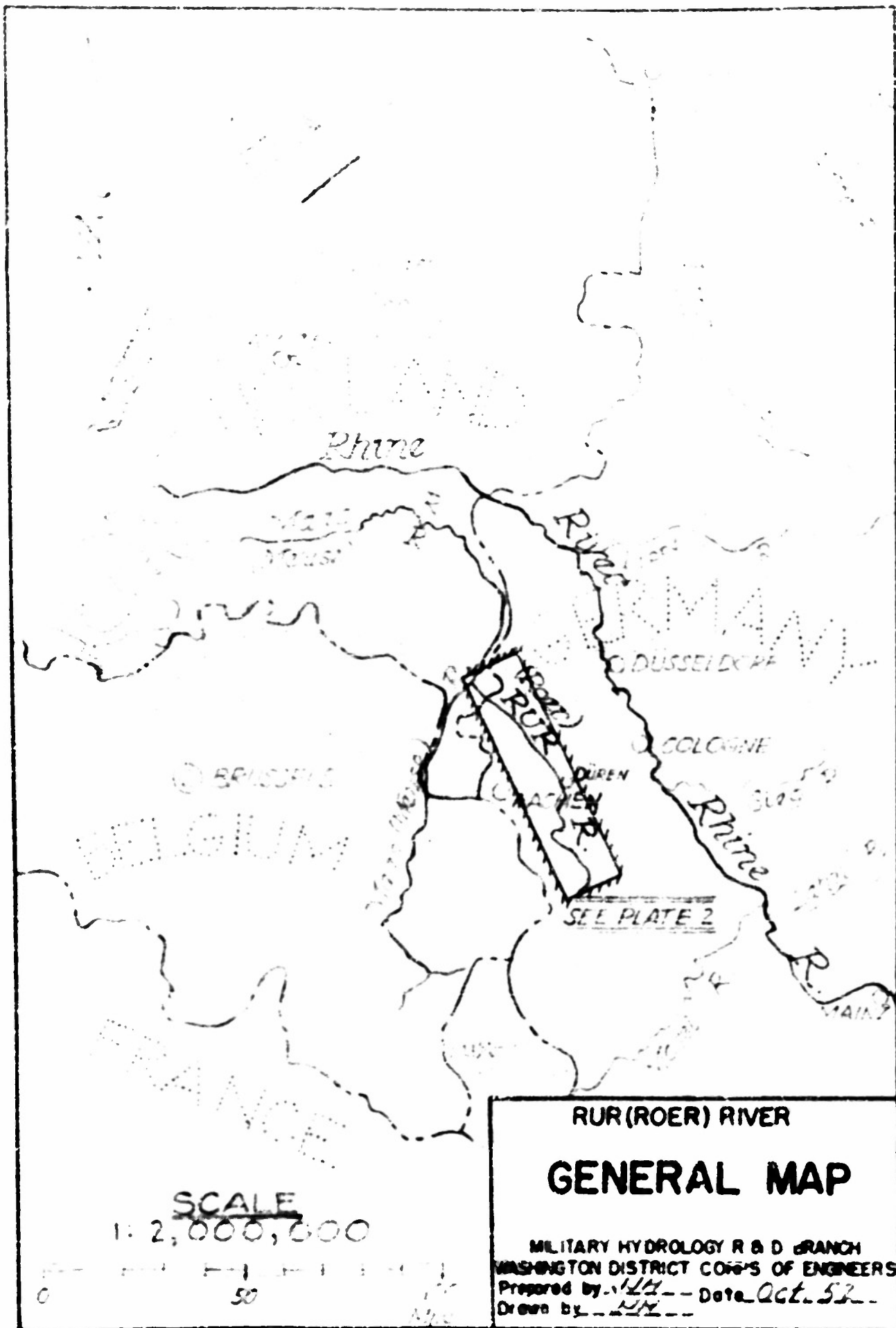
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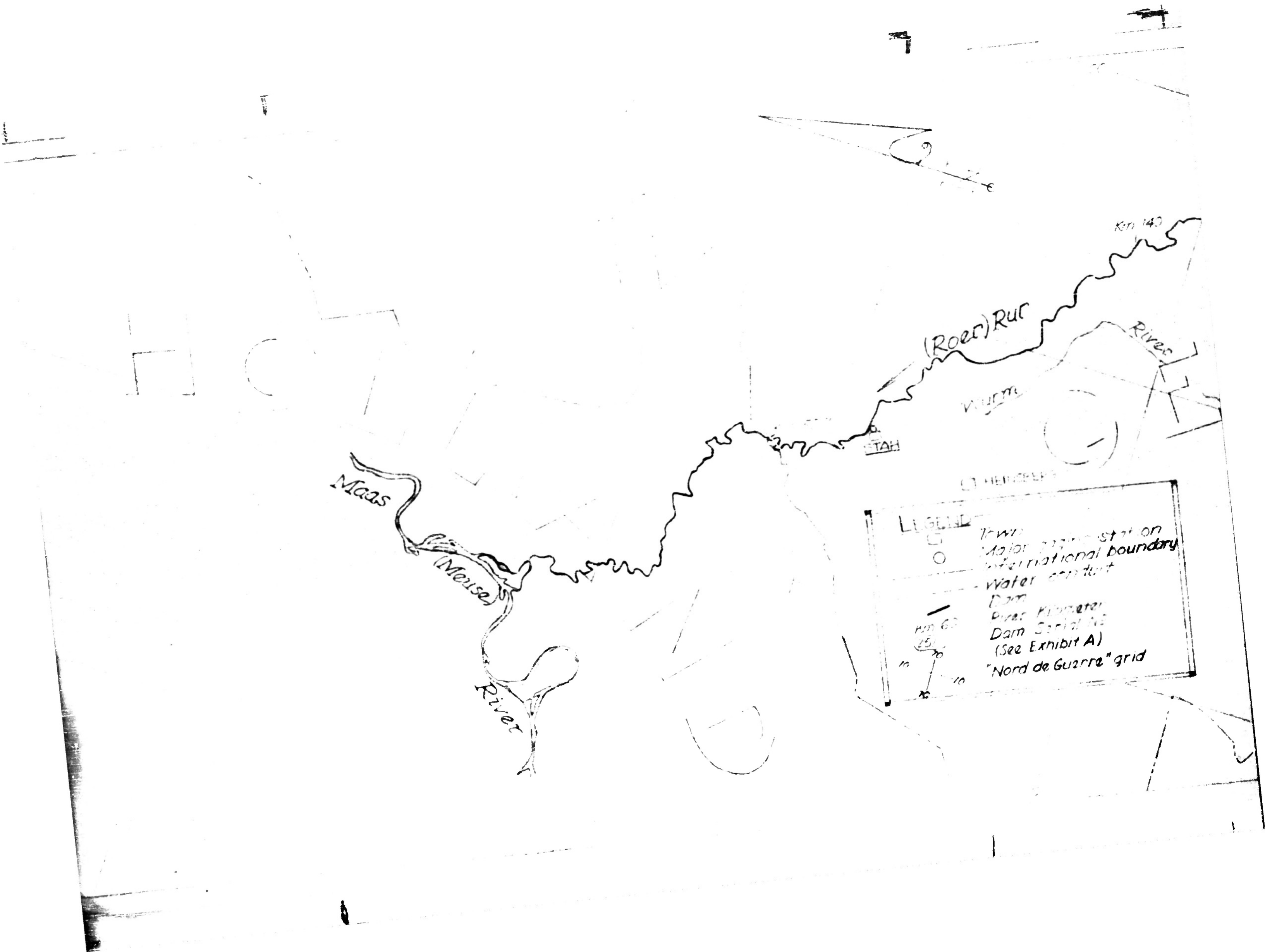
PLATES

1. General Map
2. River Basin Map
3. Drainage Basin Map
4. Stream Profile, Rur River
5. Channel and Flood-Plain Widths
6. Sketches of Dam, Urft Dam
7. Sketches of Dam, (Schwammensauel) Rur
8. Sketches of Dams, Paulushof, Heimbach and Obermaubach
9. Sketches of Dams, Kall and Dreilägerbach
10. Depth, Discharge and Velocity Profiles
11. Stage, Discharge and Velocity Duration Curves
12. Stage, Discharge and Velocity Monthly Variation
13. Discharge and Velocity Rating Curves
14. Inundation by Still-Water Barriers
15. Reservoir Storage Curves; Rur, Urft and Paulushof
16. Reservoir Storage Curves; Kall, Dreilägerbach, Heimbach and Obermaubach
17. Hydrographs, Major Flood Wave, Urft and Rur Dam Breach
18. Hydrographs, Major Flood Waves, Kall and Dreilägerbach
19. Hydrographs, Flow Variation, Urft and Rur Dams
20. Hydrographs, Flow Variation, Heimbach and Obermaubach
21. Hydrographs, Flow Variation, Kall and Dreilägerbach

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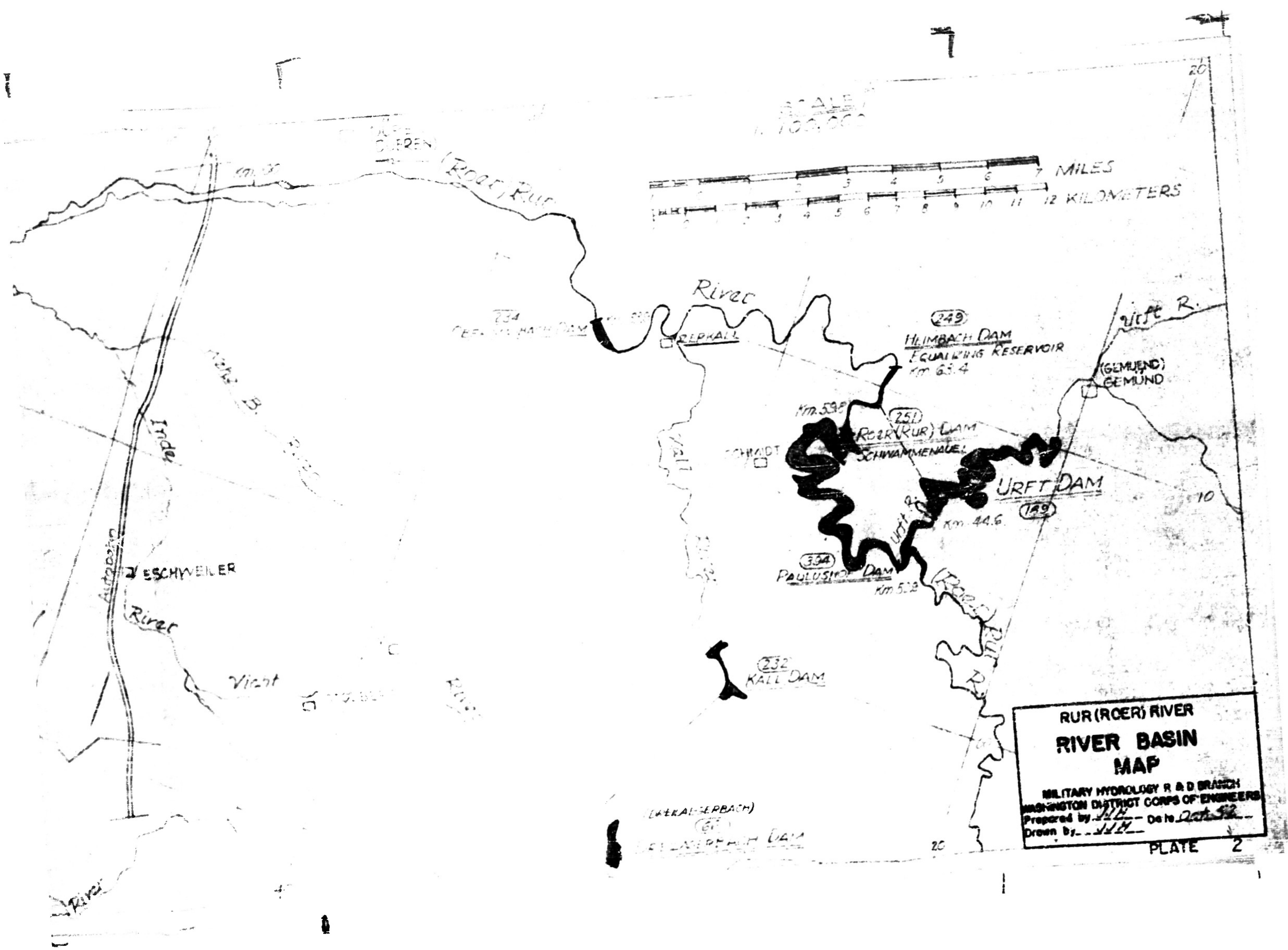
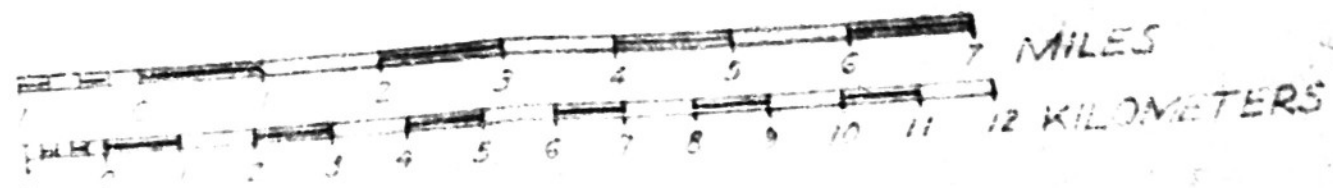
SECRET







SCALE
1:100,000



**RUR (ROER) RIVER
RIVER BASIN
MAP**
 MILITARY HYDROLOGY R & D BRANCH
 WASHINGTON DISTRICT CORPS OF ENGINEERS
 Prepared by J.H. Date Oct 52
 Drawn by J.H.

Reproduced from
"Deutsche Wasservirtschaft",
Jan. 1935, p. 2.

NIEDERLANDEN

BELGIËN



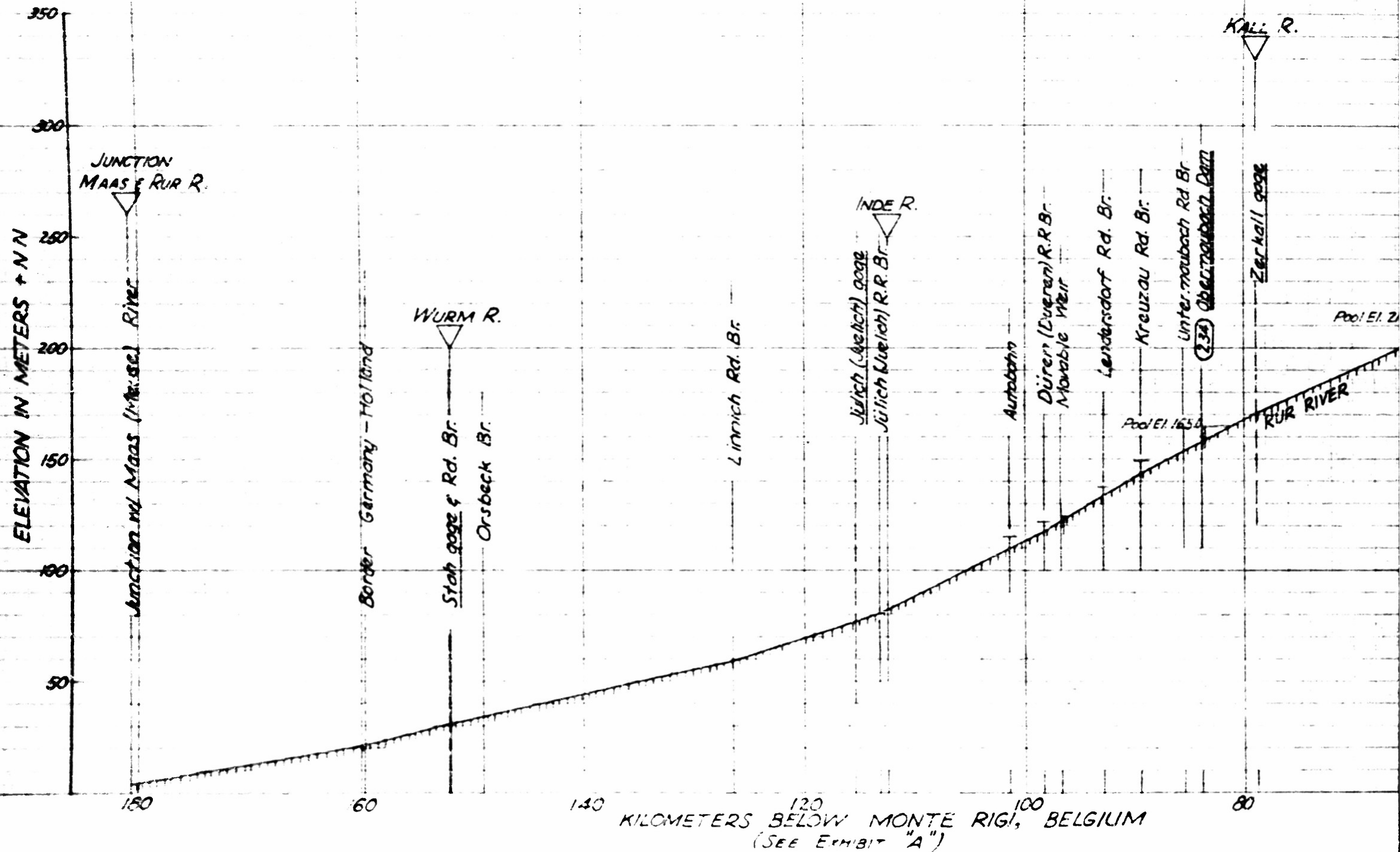
APPROXIMATE SCALE
1:400,000

- International Boundaries
- District Boundaries
- River Drainage Area

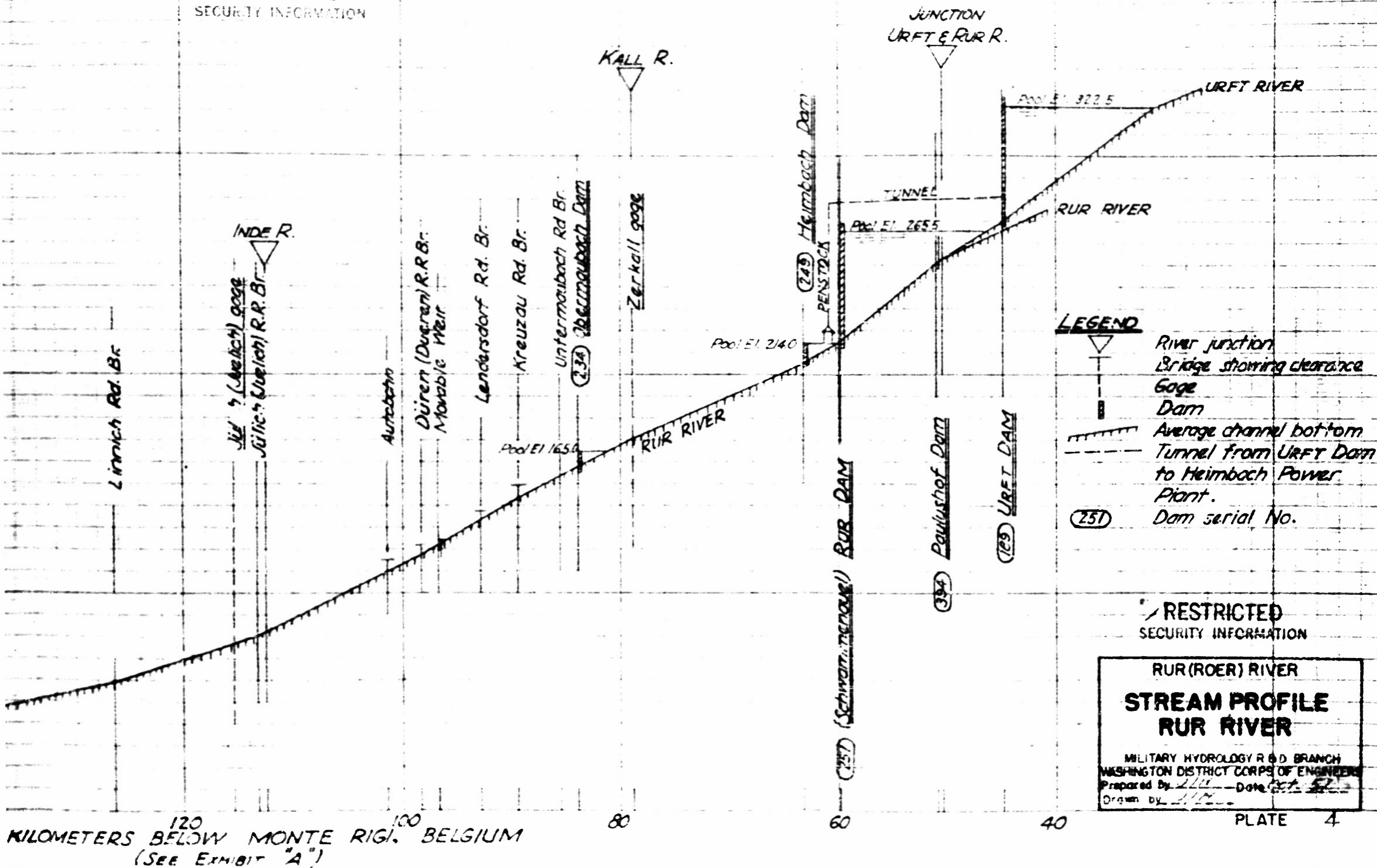
RUR (ROER) RIVER DRAINAGE BASIN MAP

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by LLH Date 10/16/52
Drawn by

RESTRICTED
SECURITY INFORMATION



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SECURITY INFORMATION



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SENSITIVE INFORMATION

FLOODED AREA IN KILOMETERS FROM STREAM CENTERLINE

RIGHT BANK

← DIRECTION OF FLOW

LEFT BANK

Hollond

Stah gage

Oisbeck

Linnich

Jülich (Juelich) gage

Düren (Dueren)

Zerkall gage

Border Germany

(234) Oberrhein Dam

180

160

140

120

To 3.5 Km. 100

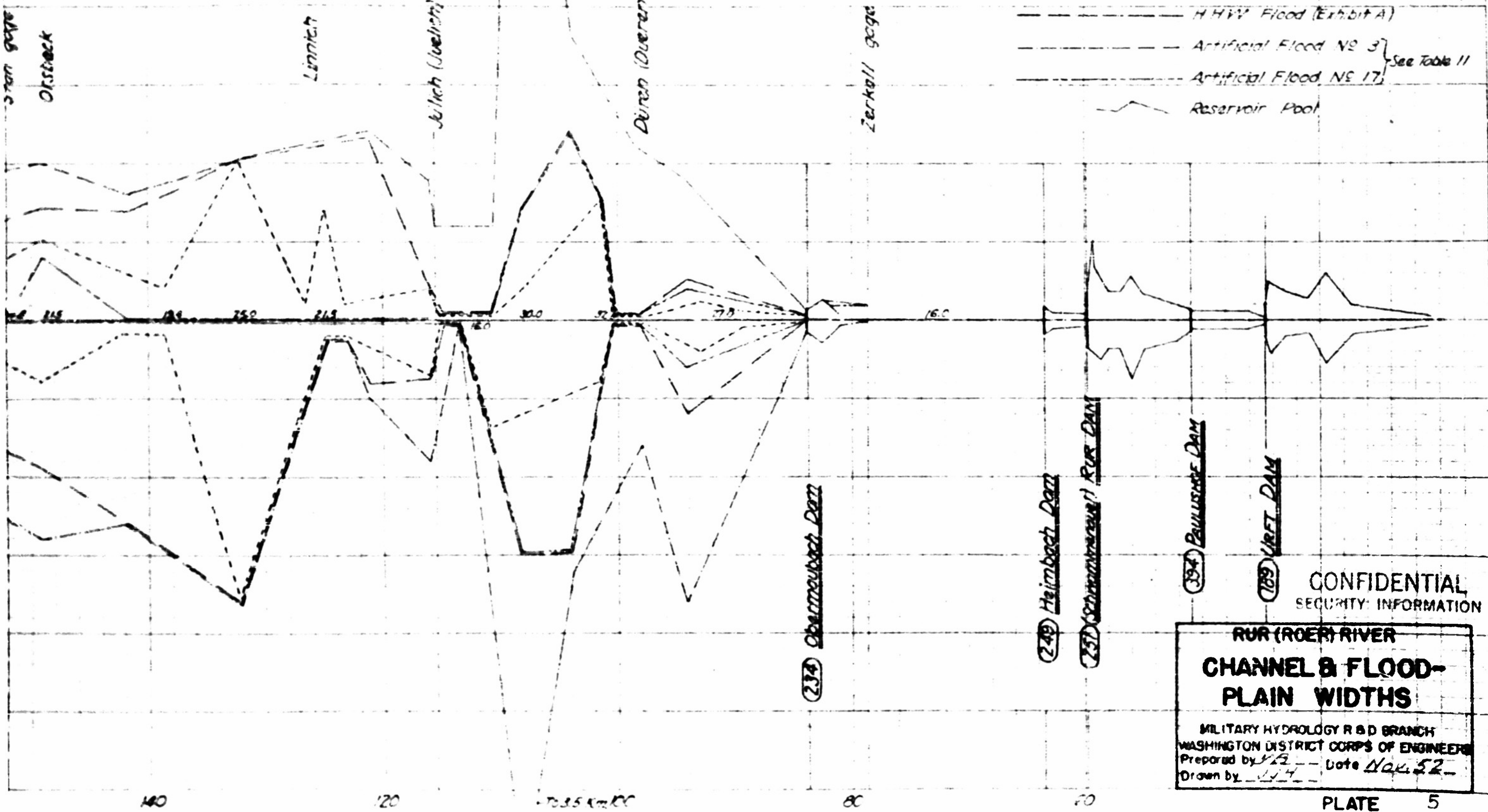
80

KILOMETERS BELOW MONTE RIGI, BELGIUM
(SEE EXHIBIT "A")

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LEGEND

- 215 Stream centerline & channel width (m)
 - Limit of Normal Flood-plain
 - H.H.V. Flood (Exhibit A)
 - Artificial Flood No 3
 - Artificial Flood No 17
 - Reservoir Pool
- See Table II

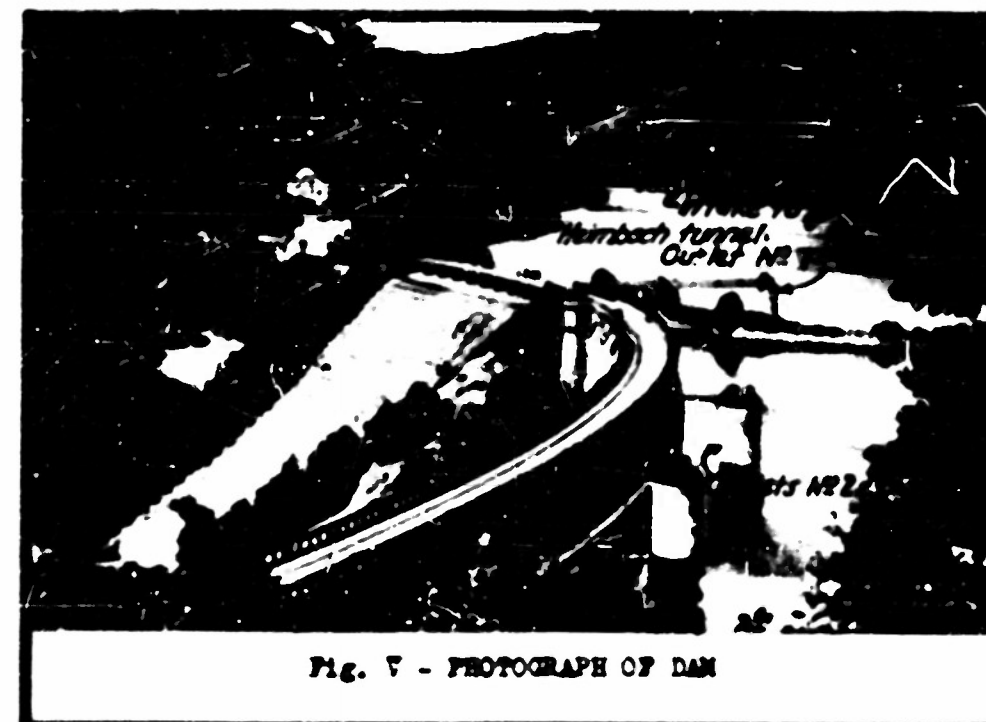
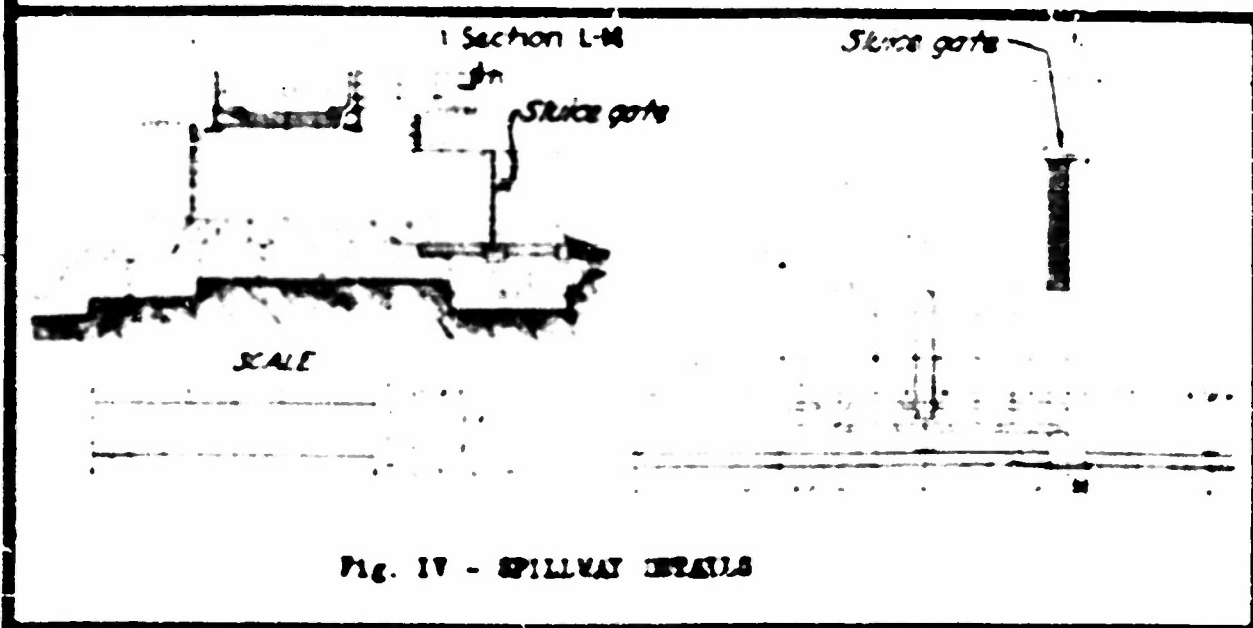
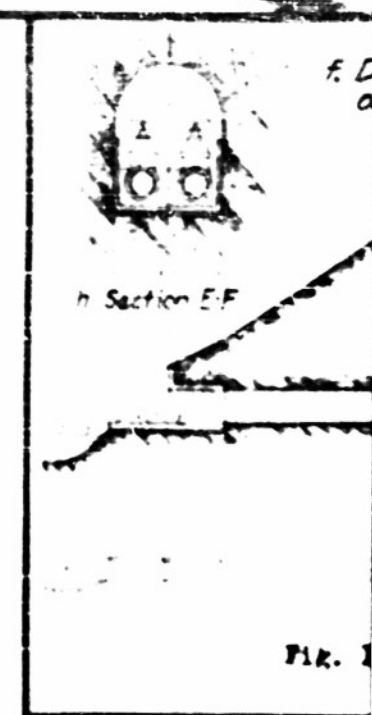
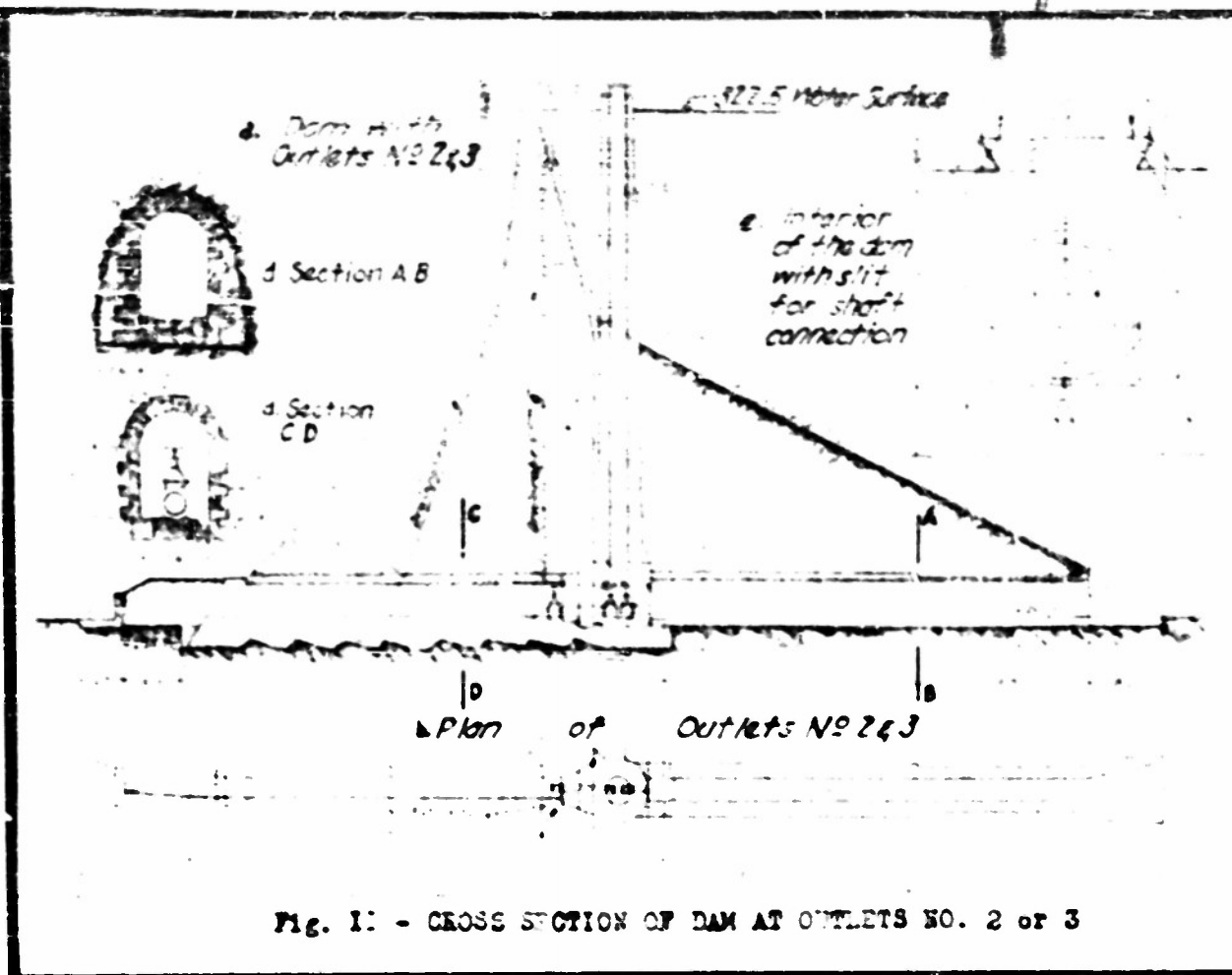
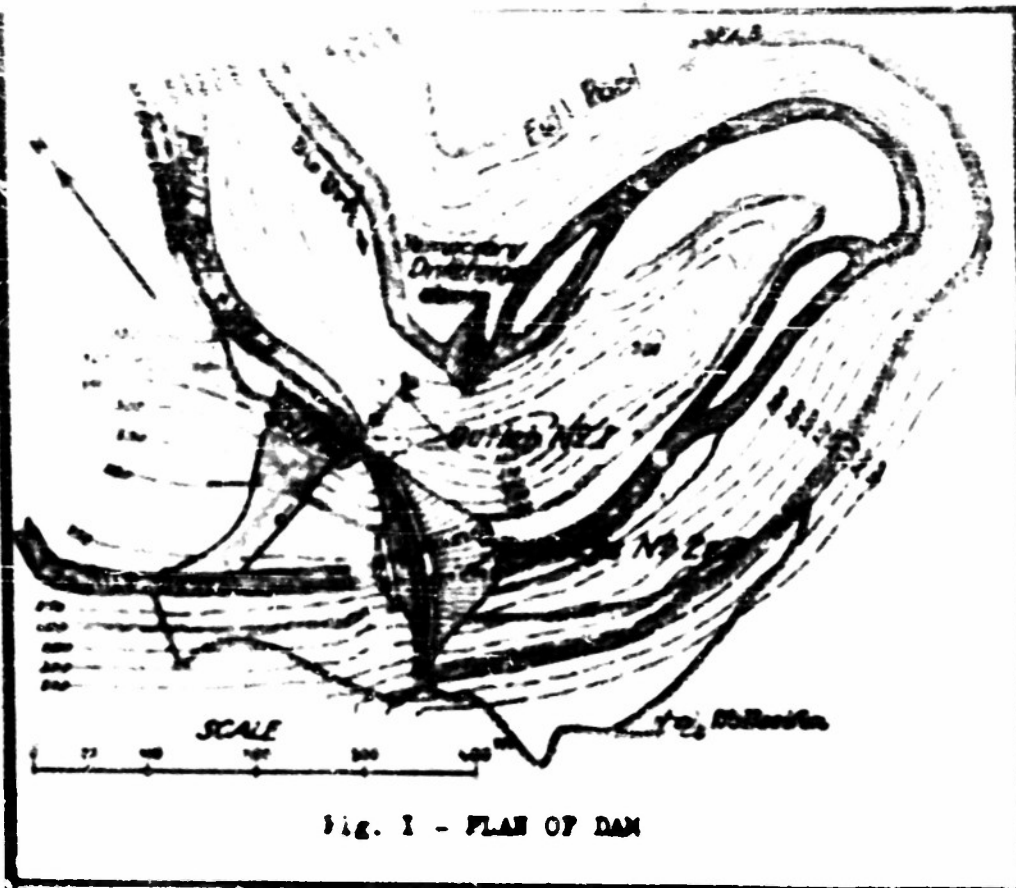


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RUR (ROER) RIVER
CHANNEL & FLOOD-PLAIN WIDTHS

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by 423 Date Nov 52
Drawn by 114

KILOMETERS BELOW MONTE RIGI, BELGIUM
(See Exhibit A)



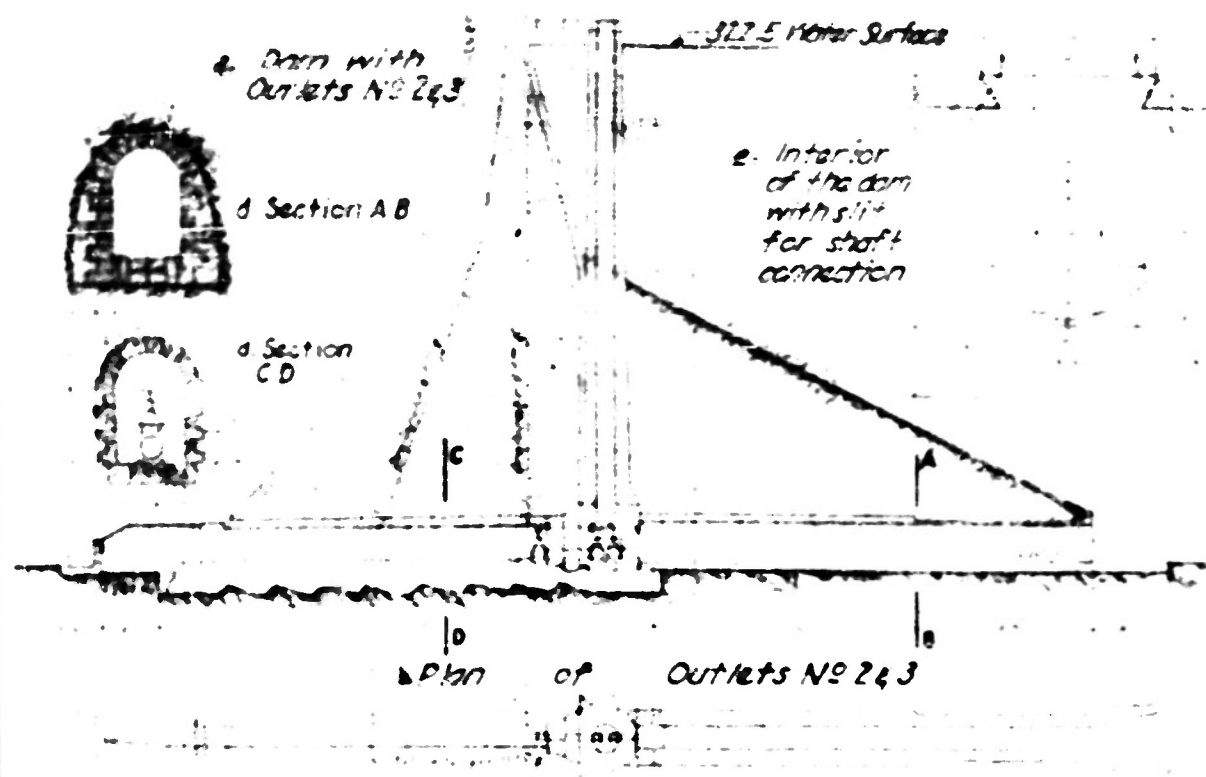


Fig. I: - CROSS SECTION OF DAM AT OUTLETS NO. 2 or 3

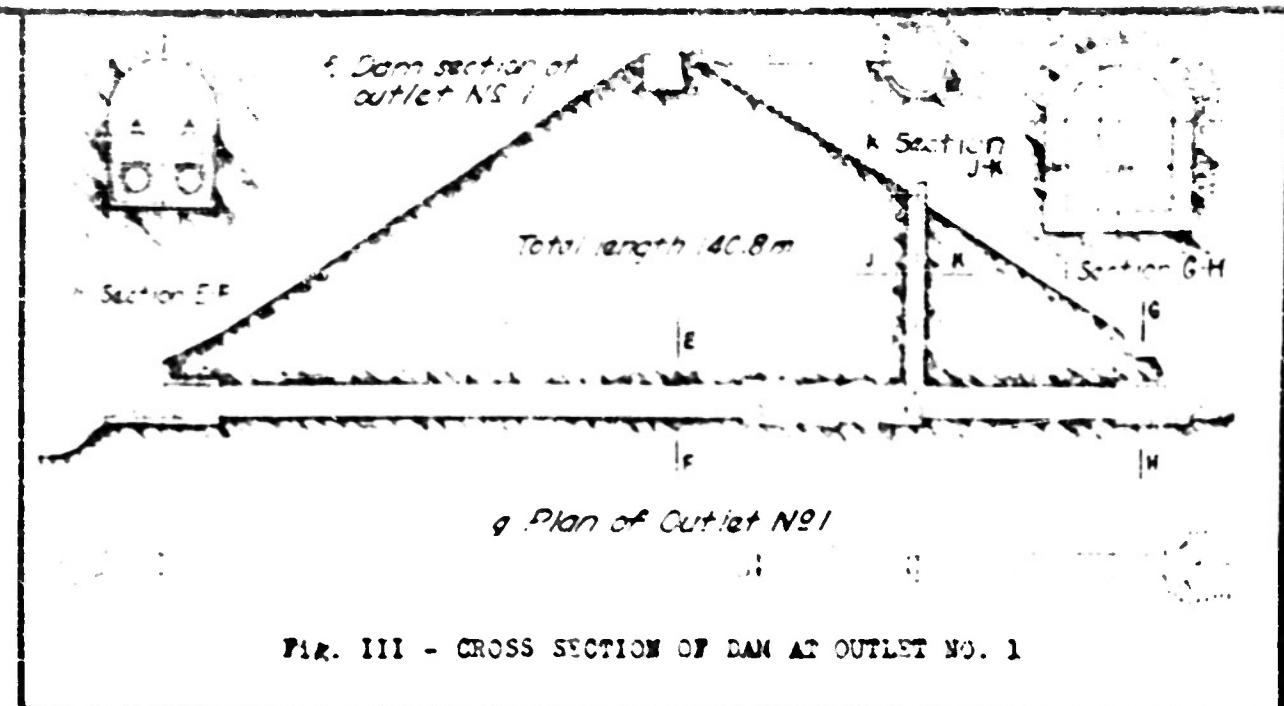


Fig. III - CROSS SECTION OF DAM AT OUTLET NO. 1

SOURCE:

- Fig. I "Deutsche Bauzeitung", 14 March 1903, p 134.
- Fig. II-IV "Deutsche Bauzeitung", 21 March 1903, p 148.
- Fig. V Frewar Gerner postcard - Karl Arens, Hotel Seehof, Genuend.

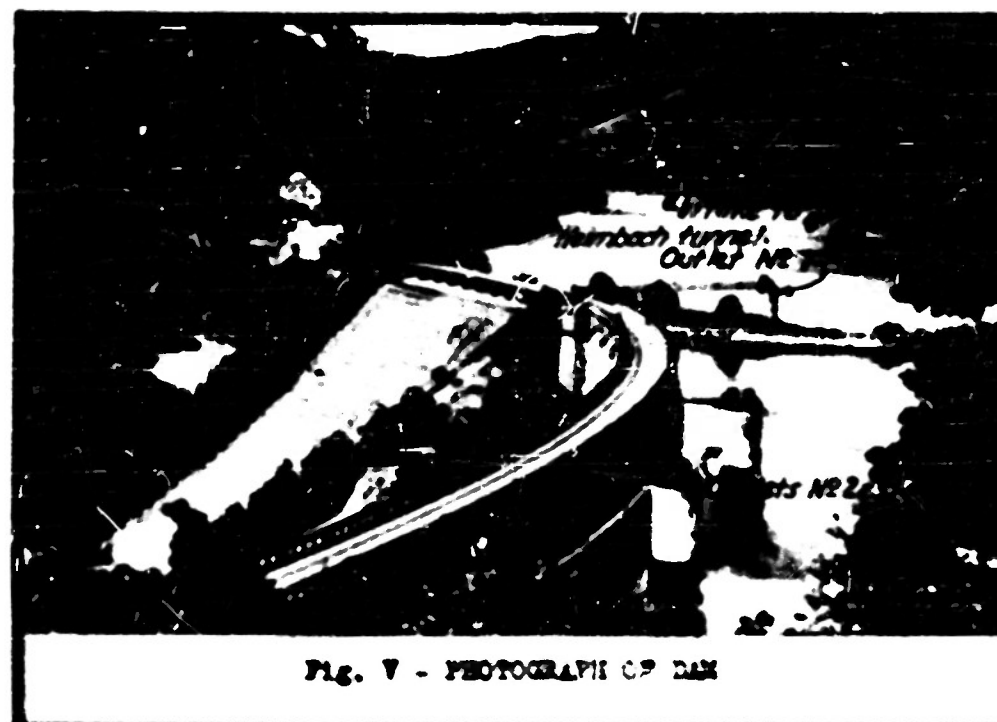


Fig. V - PHOTOGRAPH OF DAM

RUR (ROER) RIVER
SKETCHES OF DAM
URFT DAM

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JWH - Date 10/22/52
Drawn by

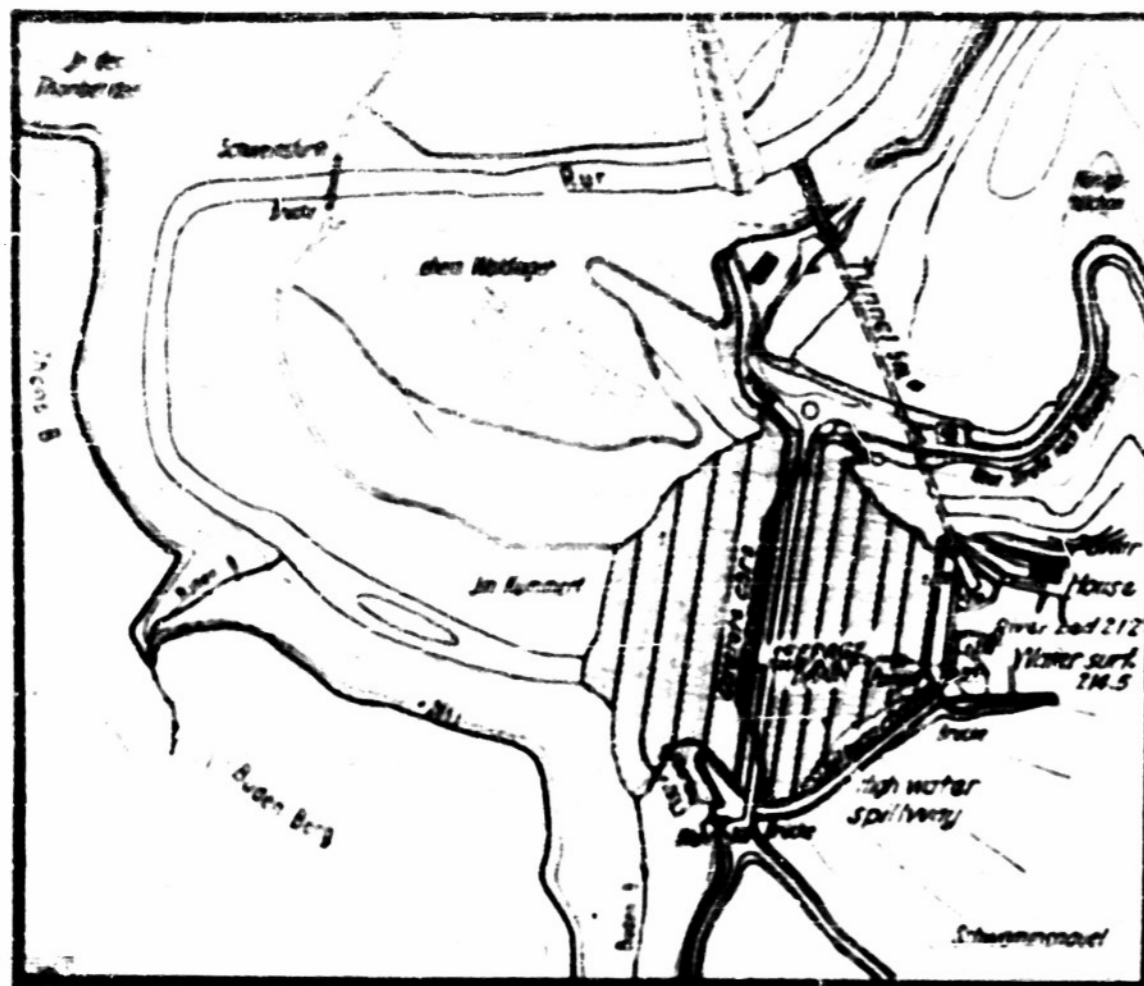


FIG. I - PLAN OF DAM

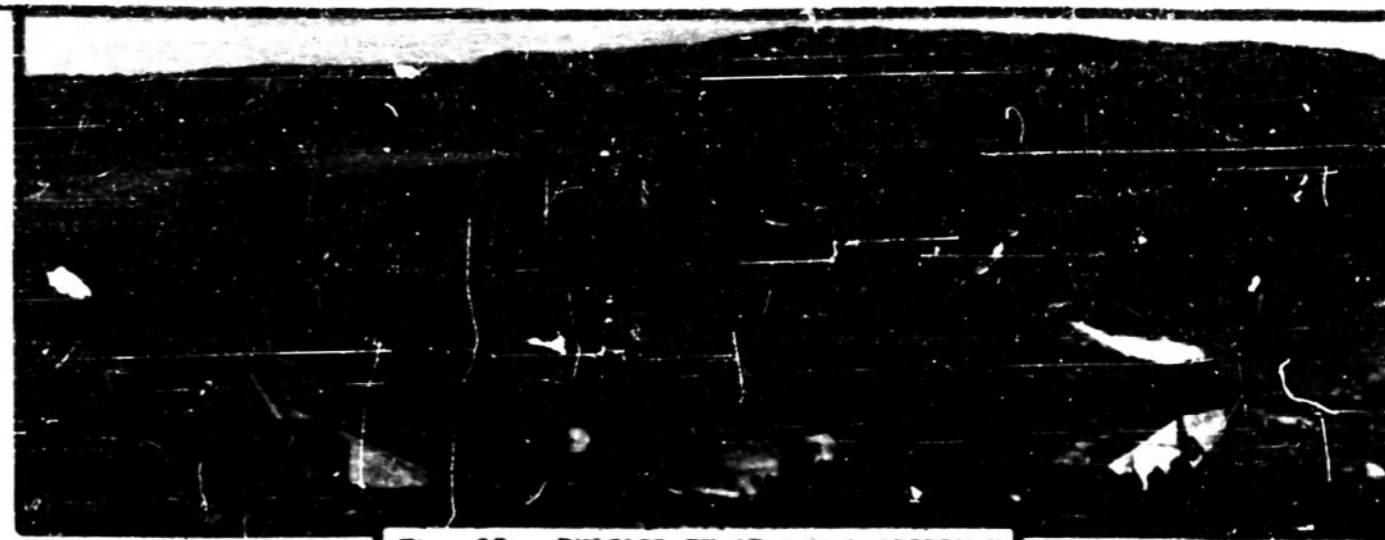


FIG. II - PHOTOGRAPH OF DAM & SPILLWAY

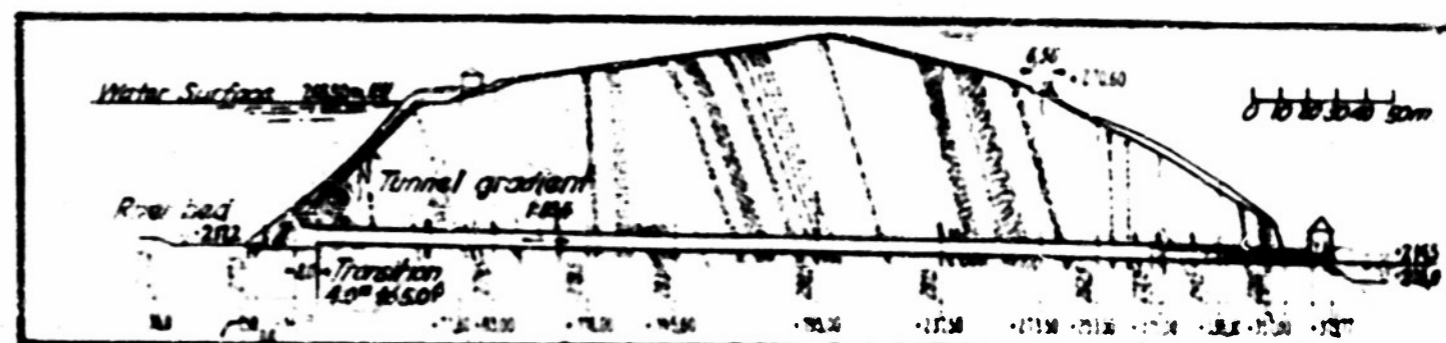


FIG. IV - PROFILE ALONG OUTLET TUNNEL

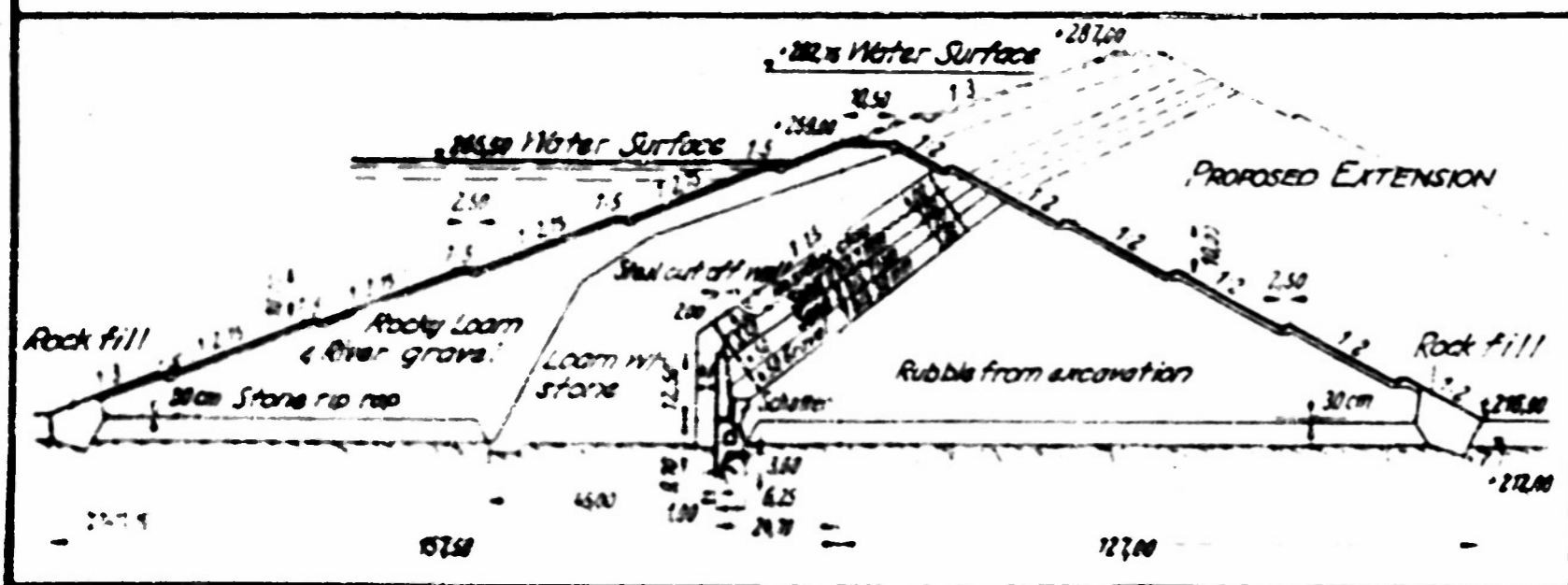


FIG. VI - CROSS SECTION OF DAM

SOURCE :

- Fig. I "VDI Zeitschrift", 25 June 1938, p 770
- Fig. II "Der Bauingenieur", Sept. 1938, p 508
- Fig. III "Deutsche Wasservirtschaft", 1938, p 133
- Fig. IV "Der Bauingenieur", Sept. 1938, p 508
- Fig. V "Deutsche Wasservirtschaft", 1938, p 133
- Fig. VI "VDI Zeitschrift", 21 Aug. 1936, p 106



FIG. II - PHOTOGRAPH OF DAM & SPILLWAY

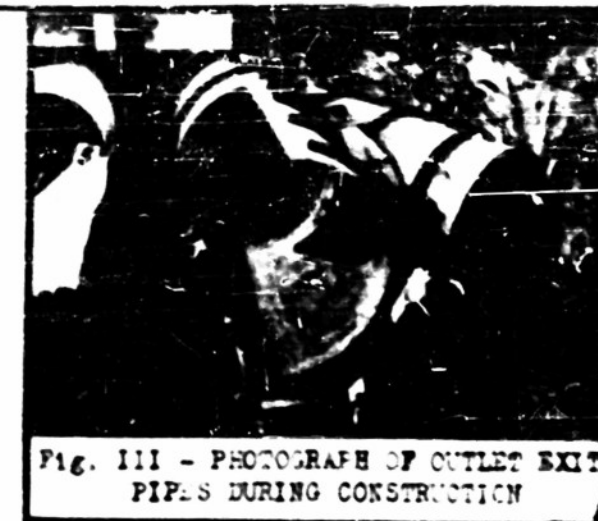


FIG. III - PHOTOGRAPH OF OUTLET EXIT PIPES DURING CONSTRUCTION

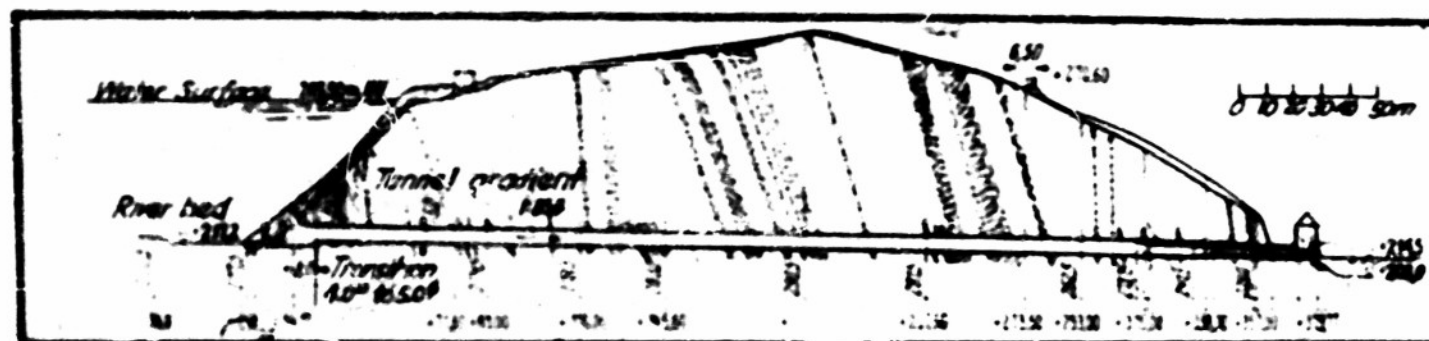


FIG. IV - PROFILE ALONG CENTER LINE

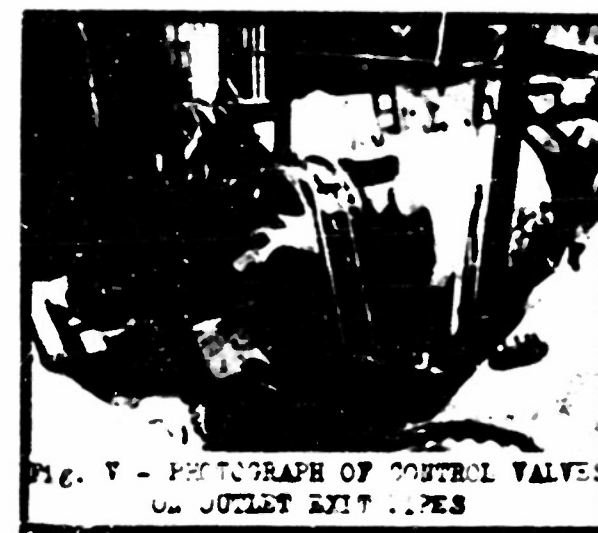
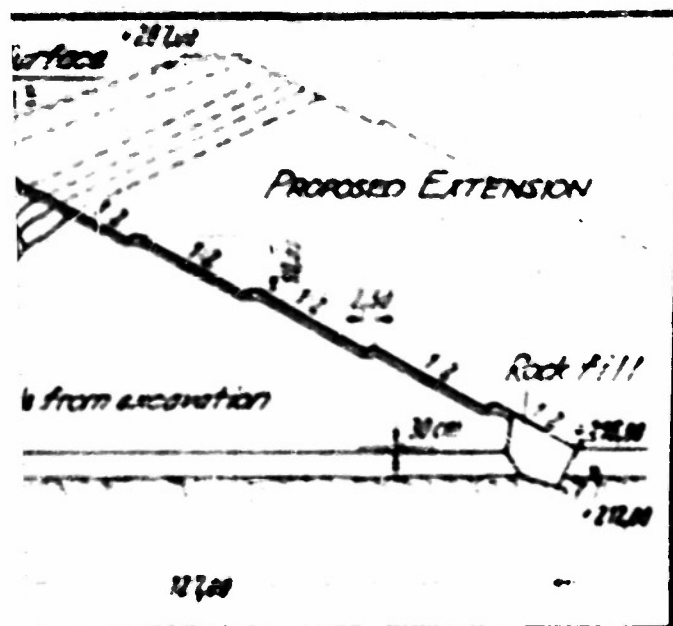


FIG. V - PHOTOGRAPH OF CONTROL VALVES OF OUTLET EXIT PIPES



DAM

SOURCE :
 FIG. I "VDI Zeitschrift", 26 June 1938, p 770
 FIG. II "Der Bauingenieur", Sept. 1938, p 508
 FIG. III "Deutsche Wasservirtschaft", 1938, p 133
 FIG. IV "Der Bauingenieur", Sept. 1938, p 508
 FIG. V "Deutsche Wasservirtschaft", 1938, p 133
 FIG. VI "VDI Zeitschrift", 21 Aug. 1936, p 1065

RUR (ROER) RIVER
 SKETCHES OF DAM
 (SCHWAMMENAUER) RUR

MILITARY HYDROLOGY R & D BRANCH
 WASHINGTON DISTRICT CORPS OF ENGINEERS
 Prepared by *WY* Date *10/21/52*
 Drawn by

PLATE

7

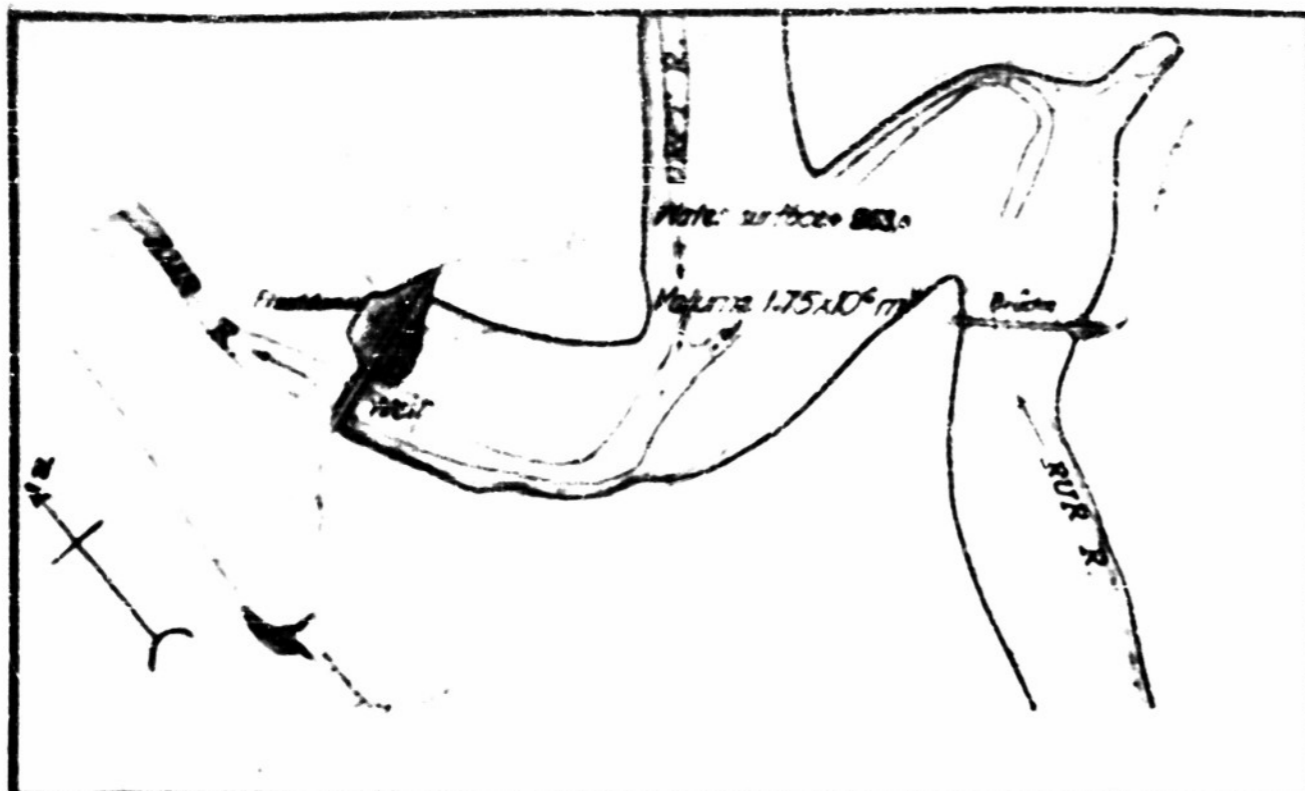


Fig. I - PAULUSHOF DAM - PLAN

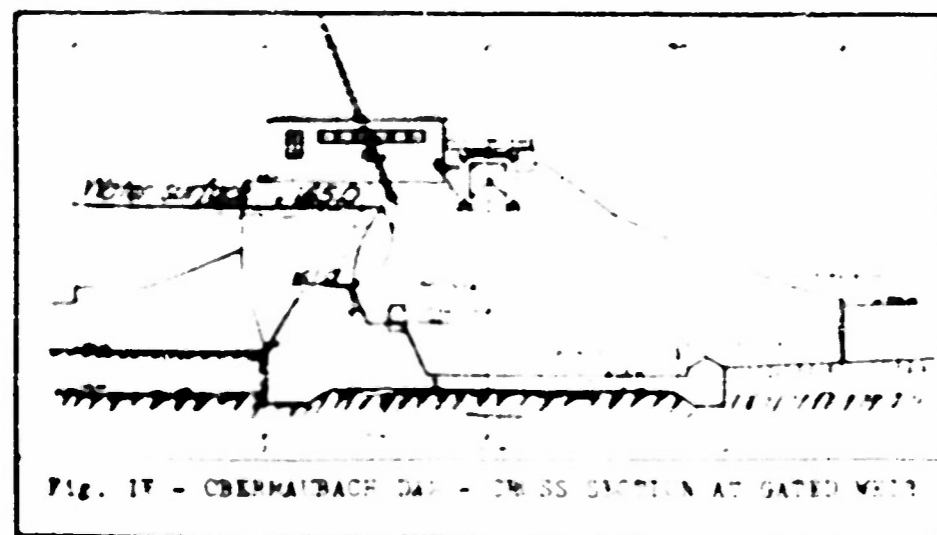


Fig. IV - OBERMAIBACH DAM - CROSS SECTION AT GATED WEIR



Fig. II - PAULUSHOF DAM - PHOTOGRAPH OF DAM

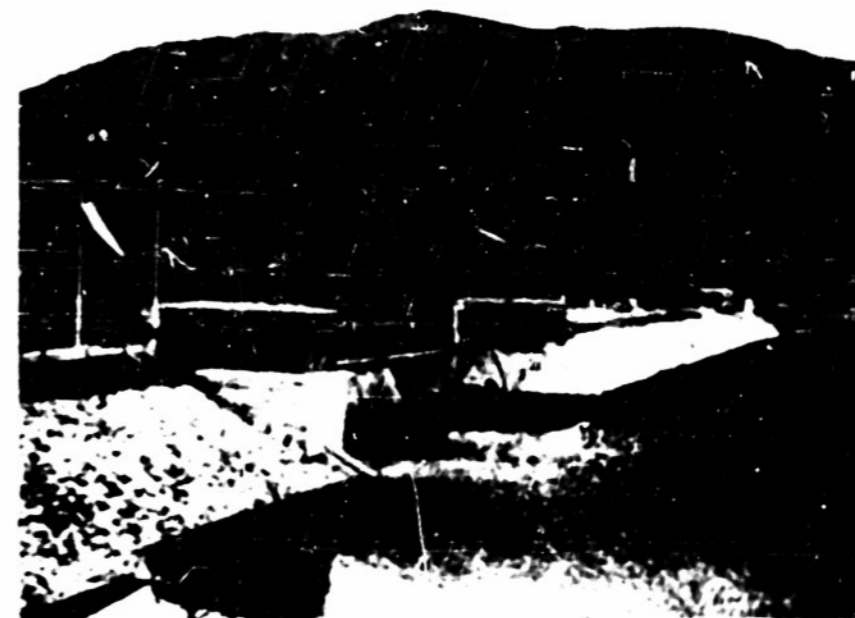


Fig. V - OBERMAIBACH DAM - PHOTOGRAPH OF DAM



Fig. VI -

SOURCE:

- Fig. I "Deutsche Wasserwirtschaft", Feb.
- Fig. II German publication (Title unknown)
- Fig. III Files of Army Map Service ESID (W Branch) (Photograph date 7/6/48).
- Fig. IV-VI "Deutsche Wasserwirtschaft", Jan



Fig. II - PAULUSHOF DAM - PHOTOGRAPH OF DAM



Fig. III - HEIMBACH DAM - PHOTOGRAPH OF DAM

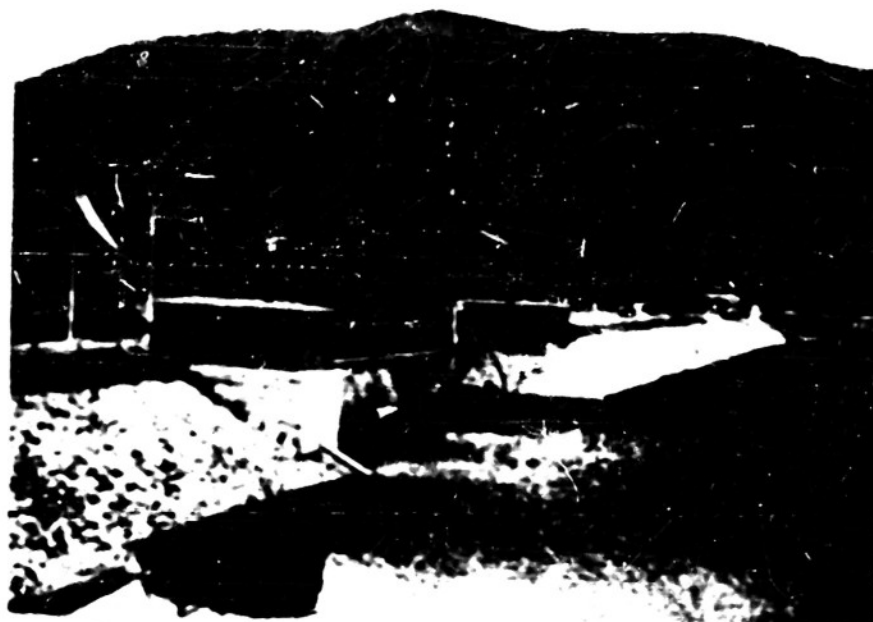
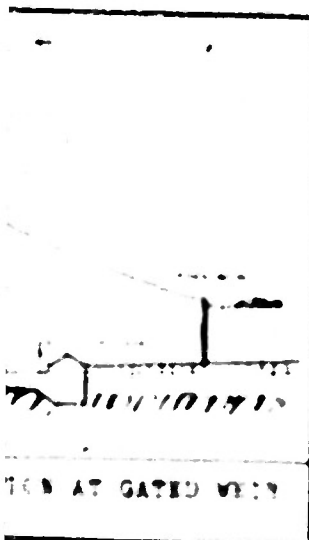


Fig. V - OBERMAUBACH DAM - PHOTOGRAPH OF DAM



Fig. VI - OBERMAUBACH DAM - PHOTOGRAPH OF VIEW GATES



VIEW AT GATED WEIR

SOURCE:

- Fig. I "Deutsche Wasserkunst", Feb. 1935, p. 29
- Fig. II German publication (Title unknown).
- Fig. III Files of Army Map Service 2510 (Western Europe Branch) (Photograph date 7/3/40).
- Fig. IV-VI "Deutsche Wasserkunst", Jan. 1935, p. 5

RUR (ROER) RIVER
SKETCHES OF DAMS
PAULUSHOF, HEIMBACH
& OBERMAUBACH

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JY Date 10/17/52
Drawn by

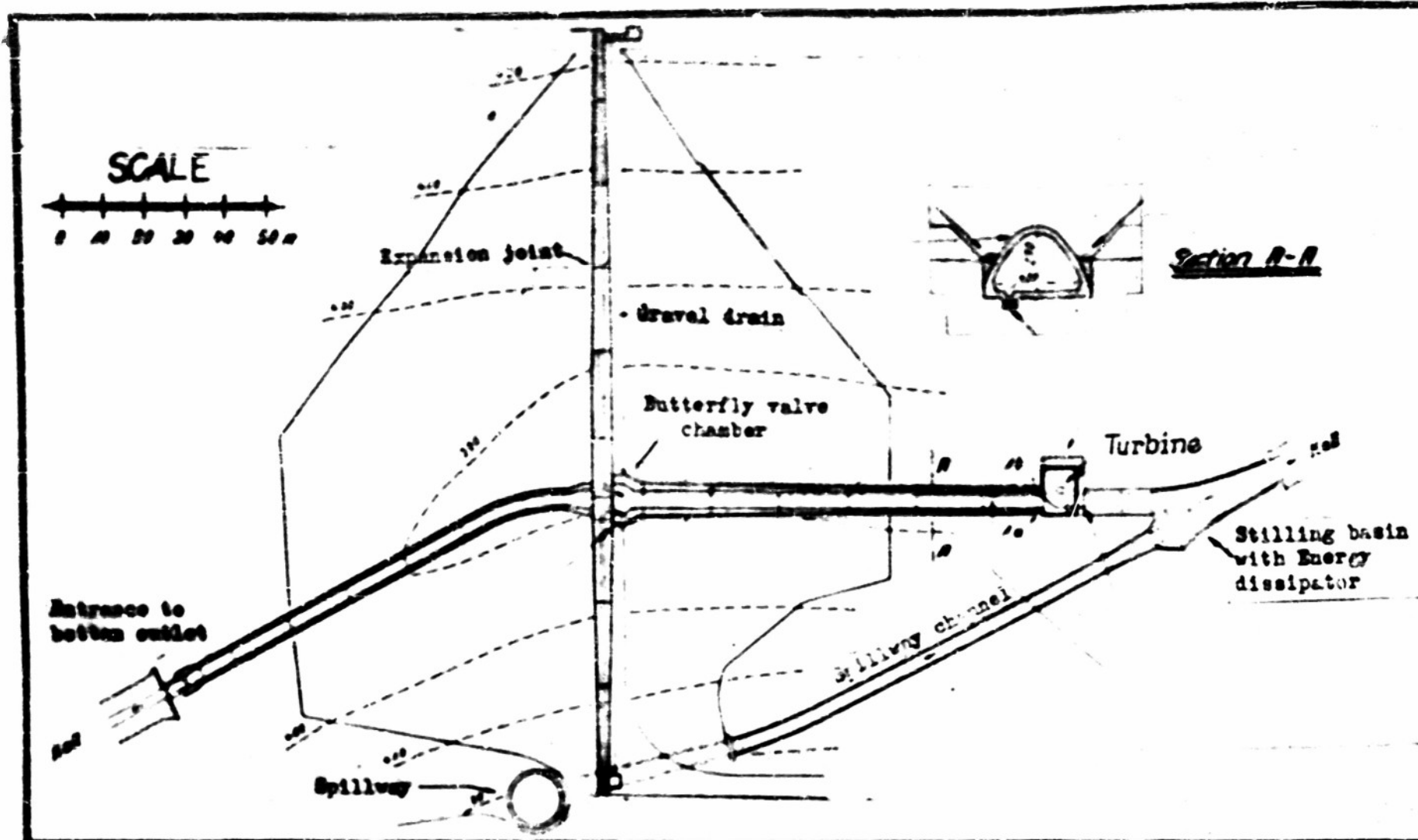


Fig. I: KALL DAM - PLAN

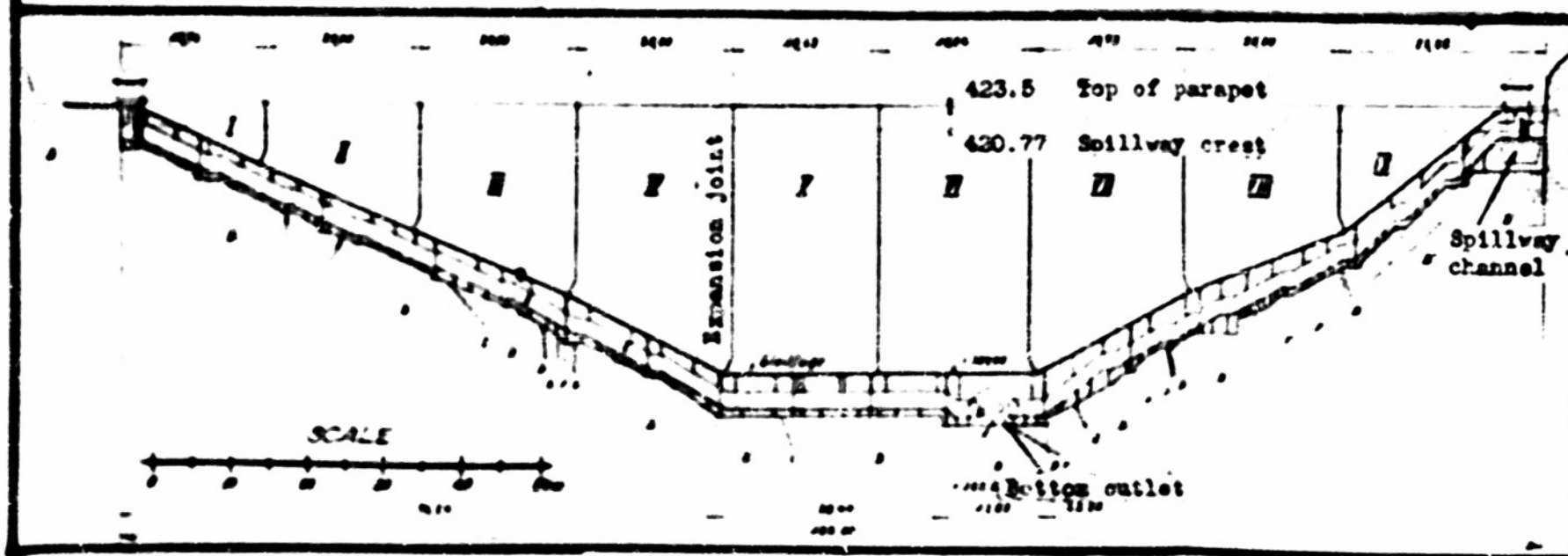


Fig. IV: KALL DAM - ELEVATION

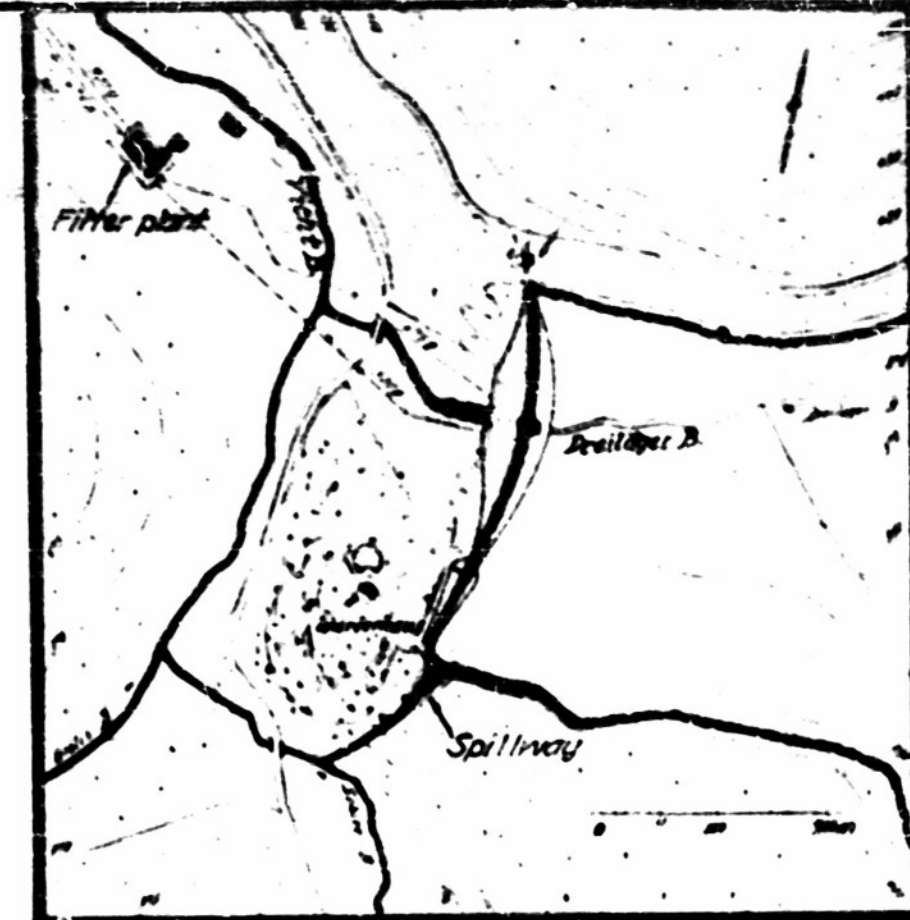


Fig. II: BREILACHENBACH DAM - PLAN

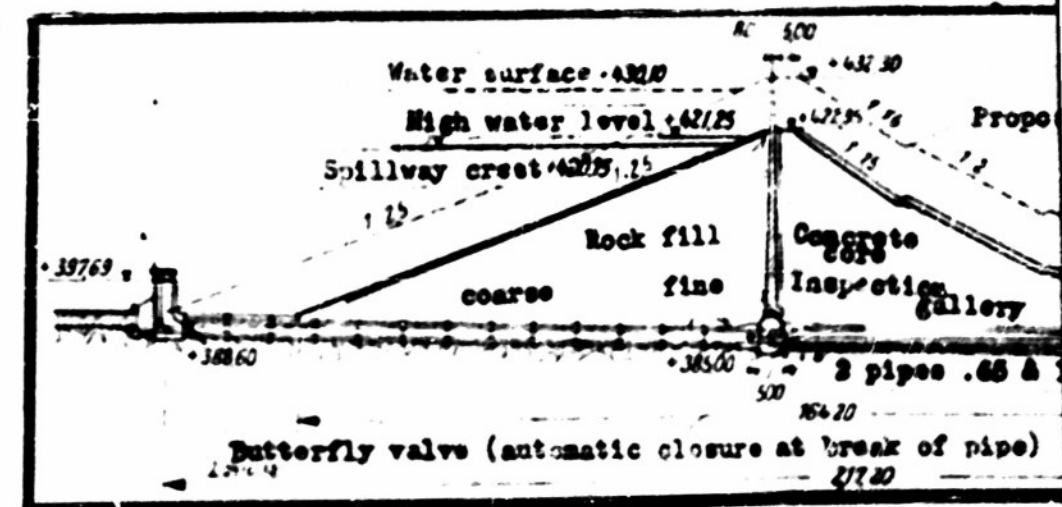
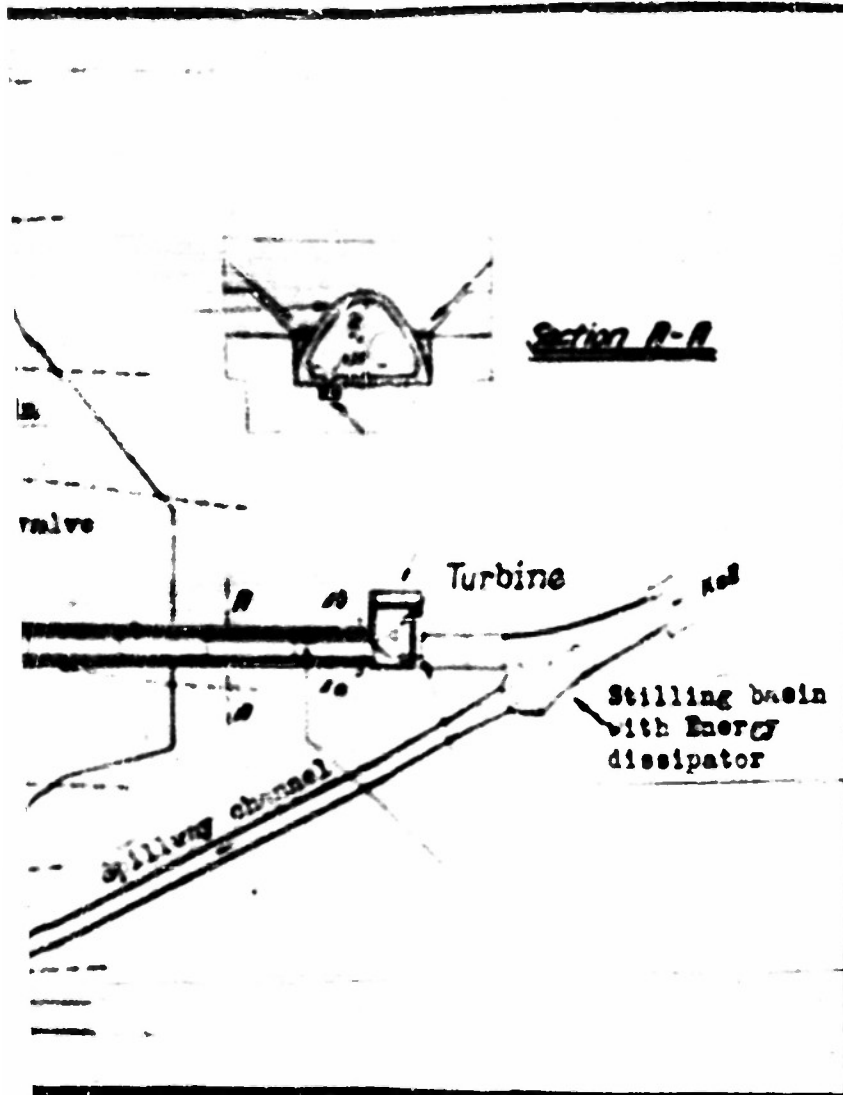
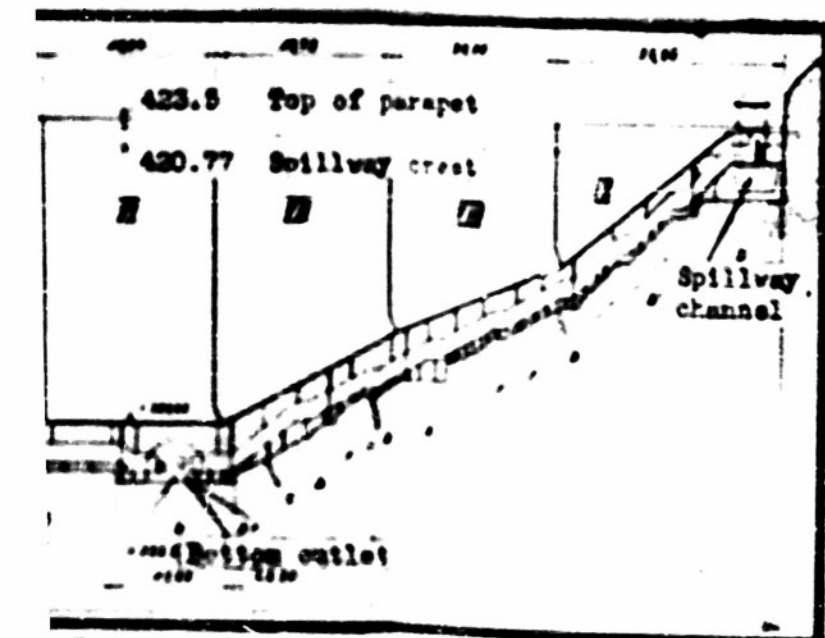


Fig. V: KALL DAM - CROSS SECTION

SOURCE:
 Fig I Deutsche Vase
 Fig II Deutsche Vase
 Fig III Deutsche Vase
 Fig IV Deutsche Vase
 Fig V VDI Zeitschrift



- PLAN



ELEVATION

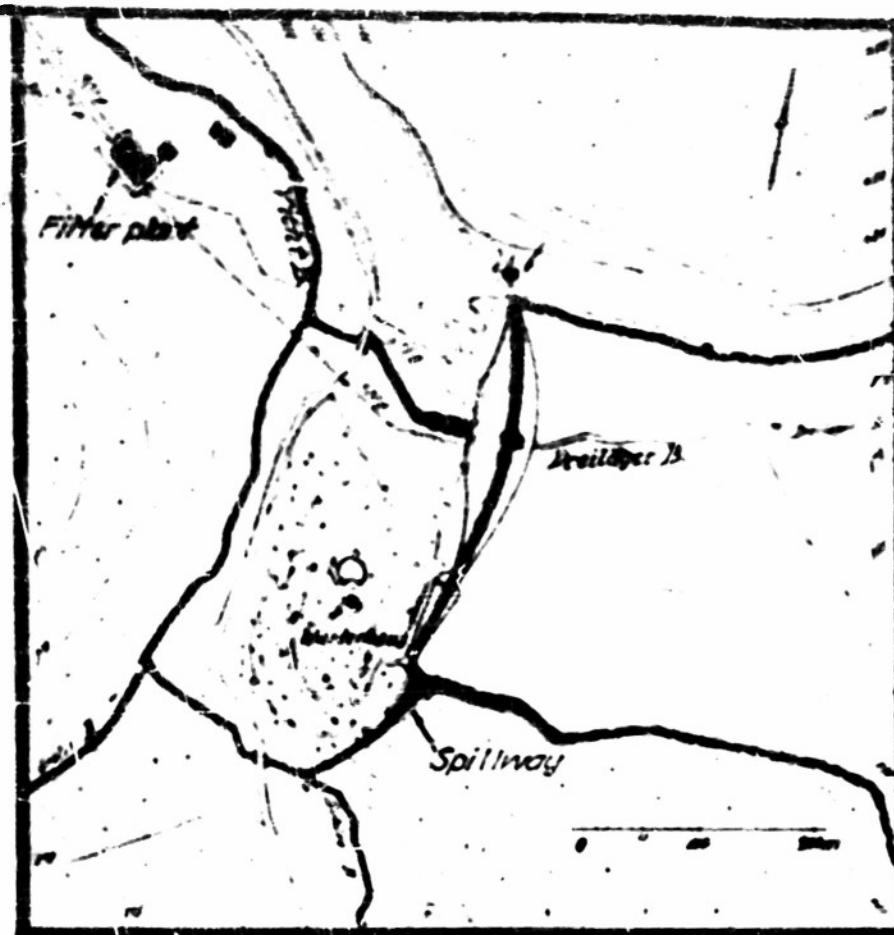


Fig. II: DREILÄGERBACH DAM - PLAN

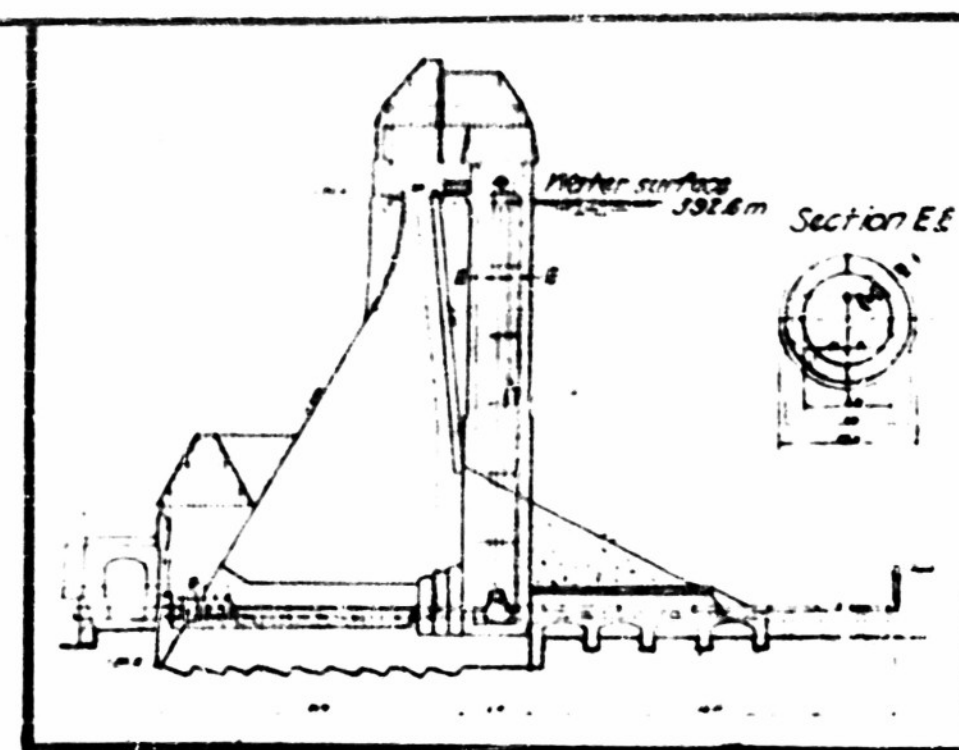


Fig. III: DREILÄGERBACH DAM - CROSS SECTION

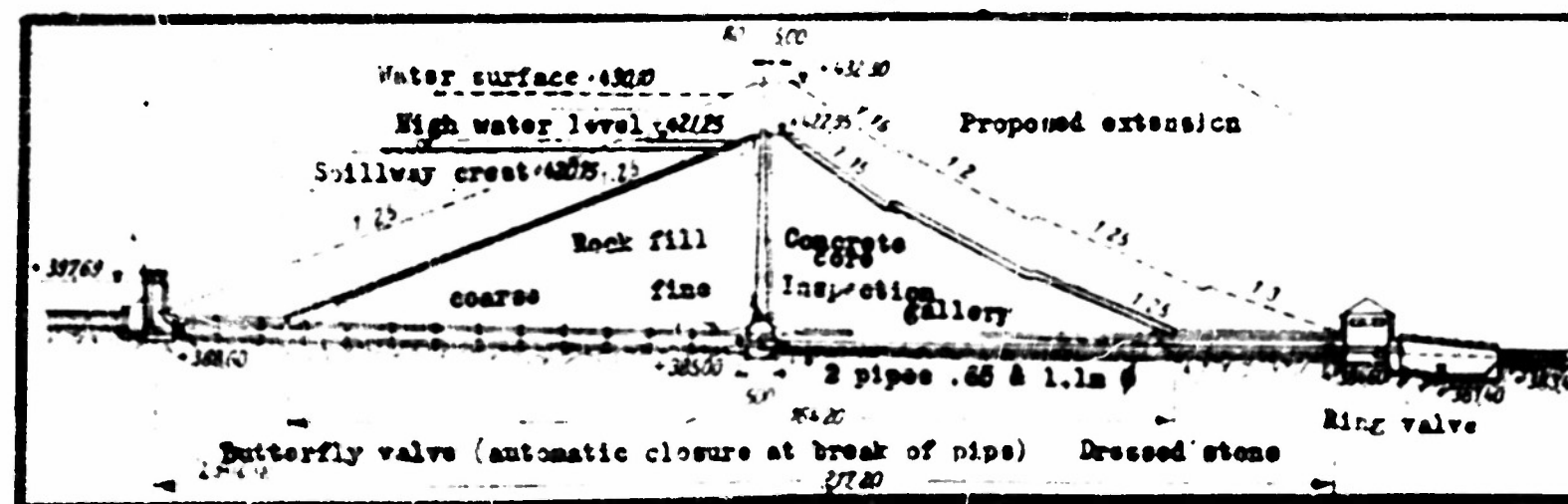


Fig. V: KALL DAM - CROSS SECTION

SOURCE:

- Fig. I "Deutsche Wasservirtschaft", 1938, p156
- Fig. II "Deutsche Wasservirtschaft", 1938, p180
- Fig. III "Deutsche Wasservirtschaft", 1938, p180
- Fig. IV "Deutsche Wasservirtschaft", 1938, p184
- Fig. V "VWL Zeitschrift", 22 Aug. 1936, p1066

RUR (ROER) RIVER

SKETCHES OF DAMS

KALL & DREILÄGERBACH

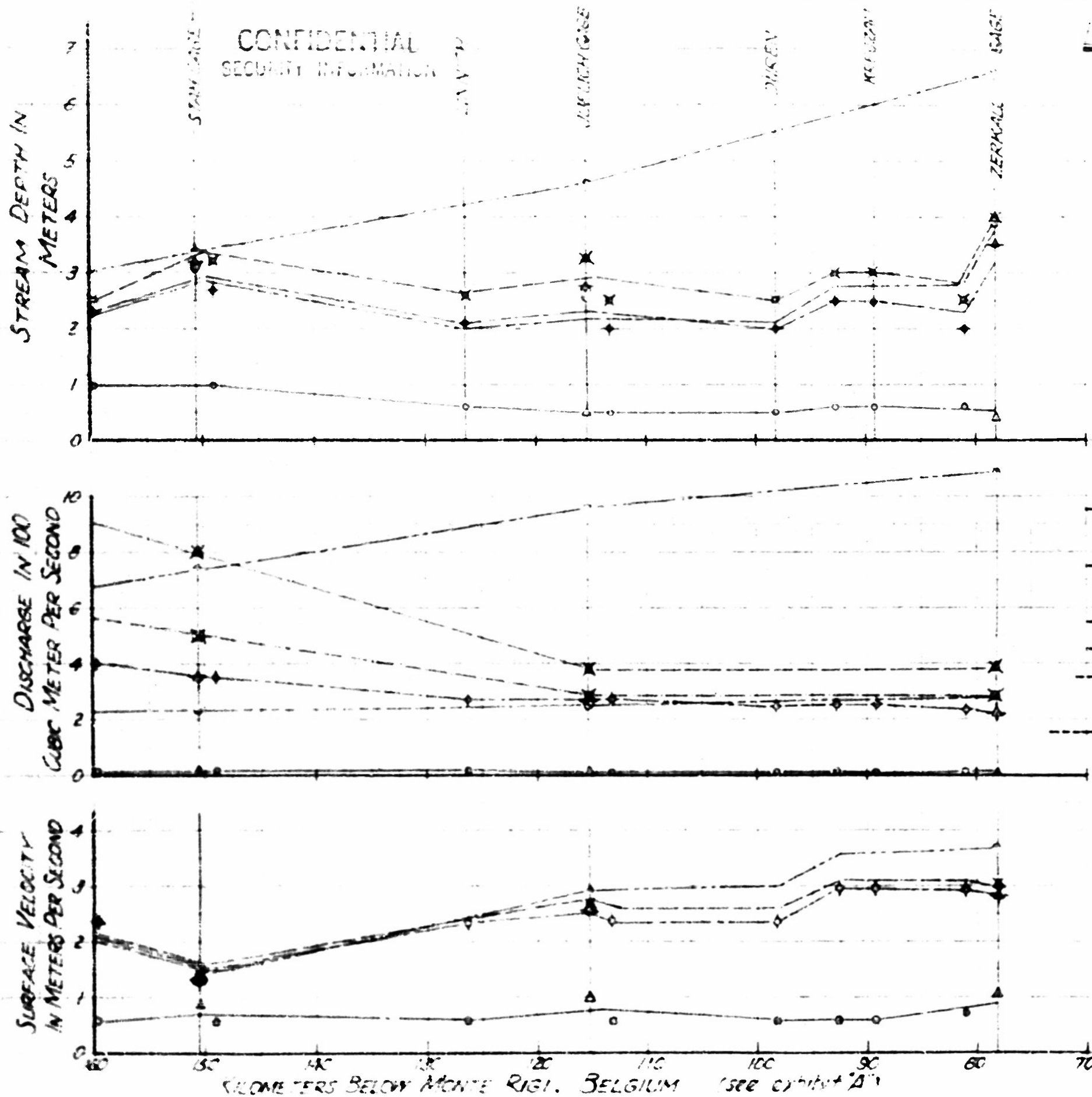
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WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by *AL* Date 10/20/52

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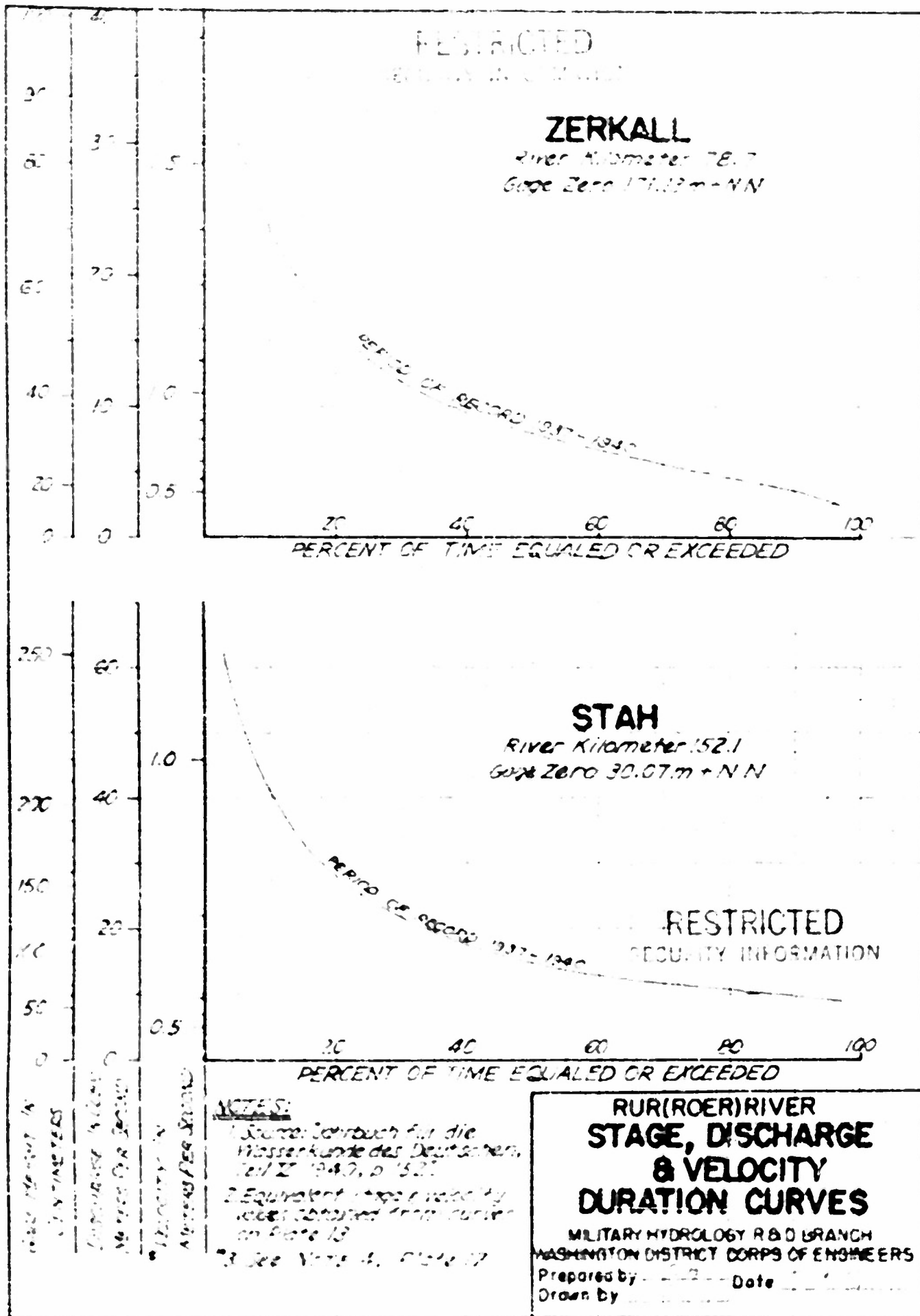
LEGEND

- ✱ Values of H_{HW} from Exhibit A.
- ◆ Values of H_{SchW} from Exhibit A.
- Values of H_{MW} from Exhibit A.
- ✱ Values, computed by use of Plate 13, based on H_{HW} stages in Exhibit A.
- ✱ Values, computed by use of Plate 13, based on H_{SchW} stages in Exhibit A.
- △ Values, computed by use of Plate 13 based on MW stages in Exhibit A.
- ✱ H_{HQ} Values, computed by use of Plate 13, based on H_{HW} stages in Table 5.
- Values for Artificial Flood No 1 from Table 7.
- Values for Artificial Flood No 19 from Table 9.
- Estimated profiles at H_{HW} (Exhibit A).
- Estimated profiles at H_{HQ} (Table 5).
- Estimated profiles at H_{SchW} .
- Estimated profiles at MW .
- Estimated profiles, Artificial Flood No 1 (See Table 7).
- Estimated profiles Artificial Flood No 19 (See Table 9).

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RUR (ROER) RIVER DEPTH, DISCHARGE & VELOCITY PROFILES

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by _____ Date _____
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STAH

River Discharge 1871
Stage 1871-1900

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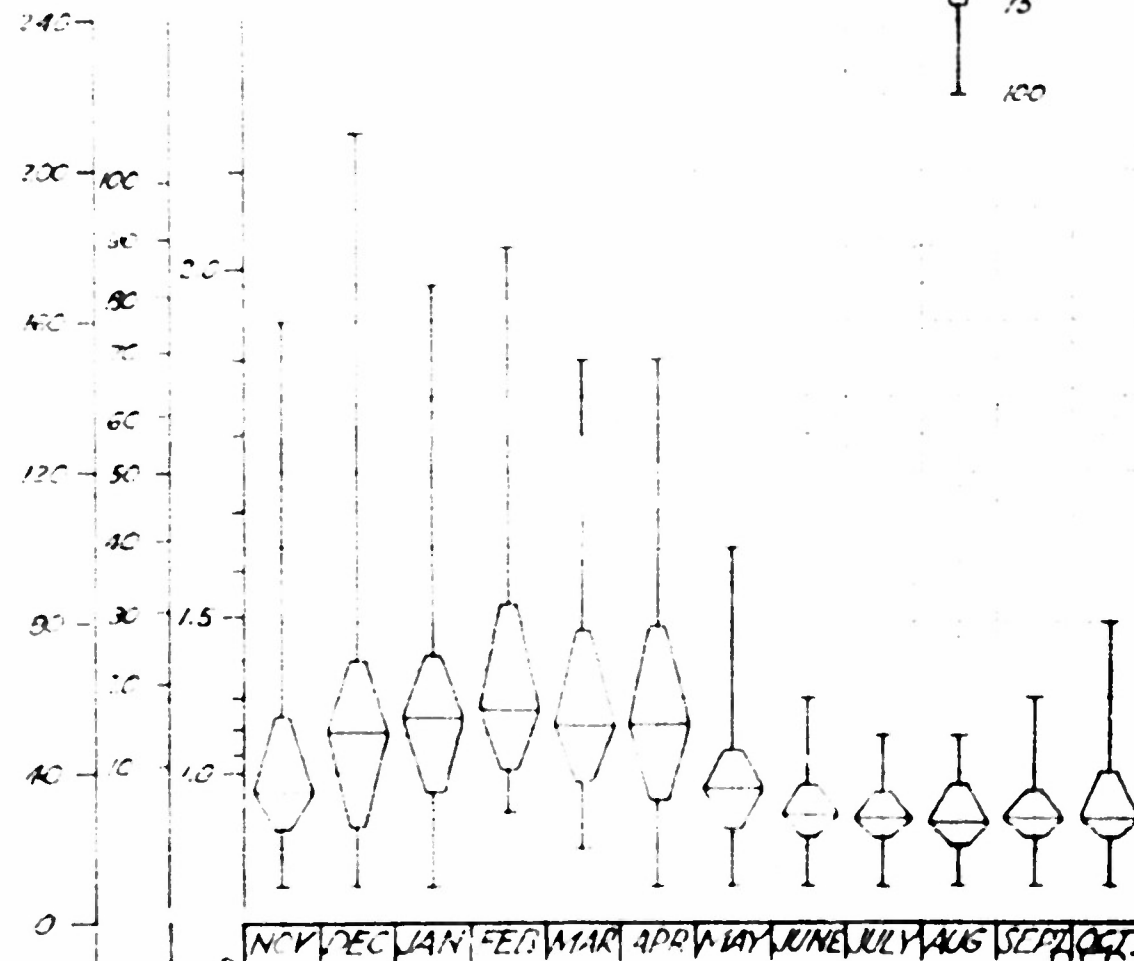
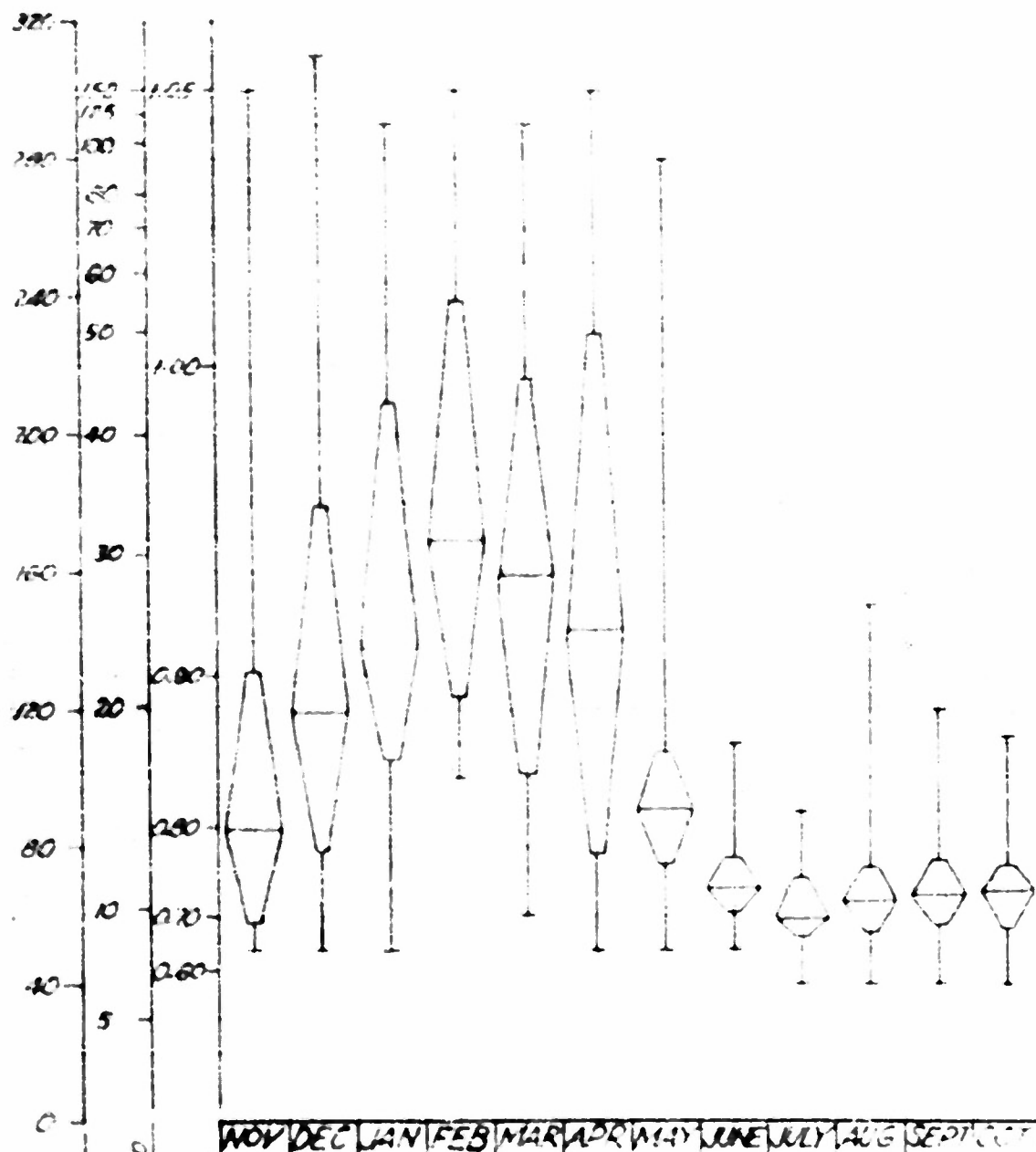
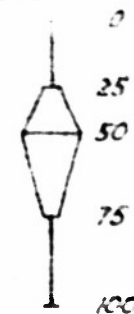
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ZERKALL

River Discharge 1871
Stage 1871-1900

LEGEND

PERCENT OF TIME EQUALLED OR EXCEEDED



NOTES:

1. Stage duration data based on occurrences of mean daily stage readings within 100m intervals over period of record covering water years 1871, 1875 & 1876.
2. Source of stage data: "Abhandl. für die Wasserkunde des Deutschen Reiches".
3. Equivalent Discharge & Velocity values obtained from curves on Plate 13.
4. Note that shown are Mean Velocities of the section. Multiply these values by 1.18 to obtain Mean Surface Velocity.

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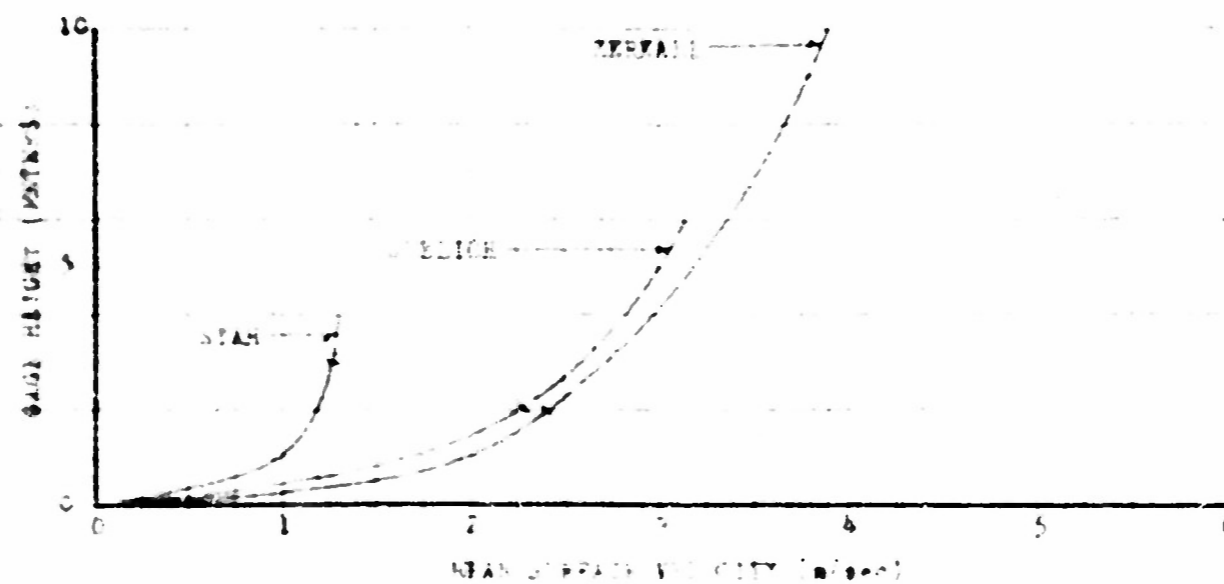
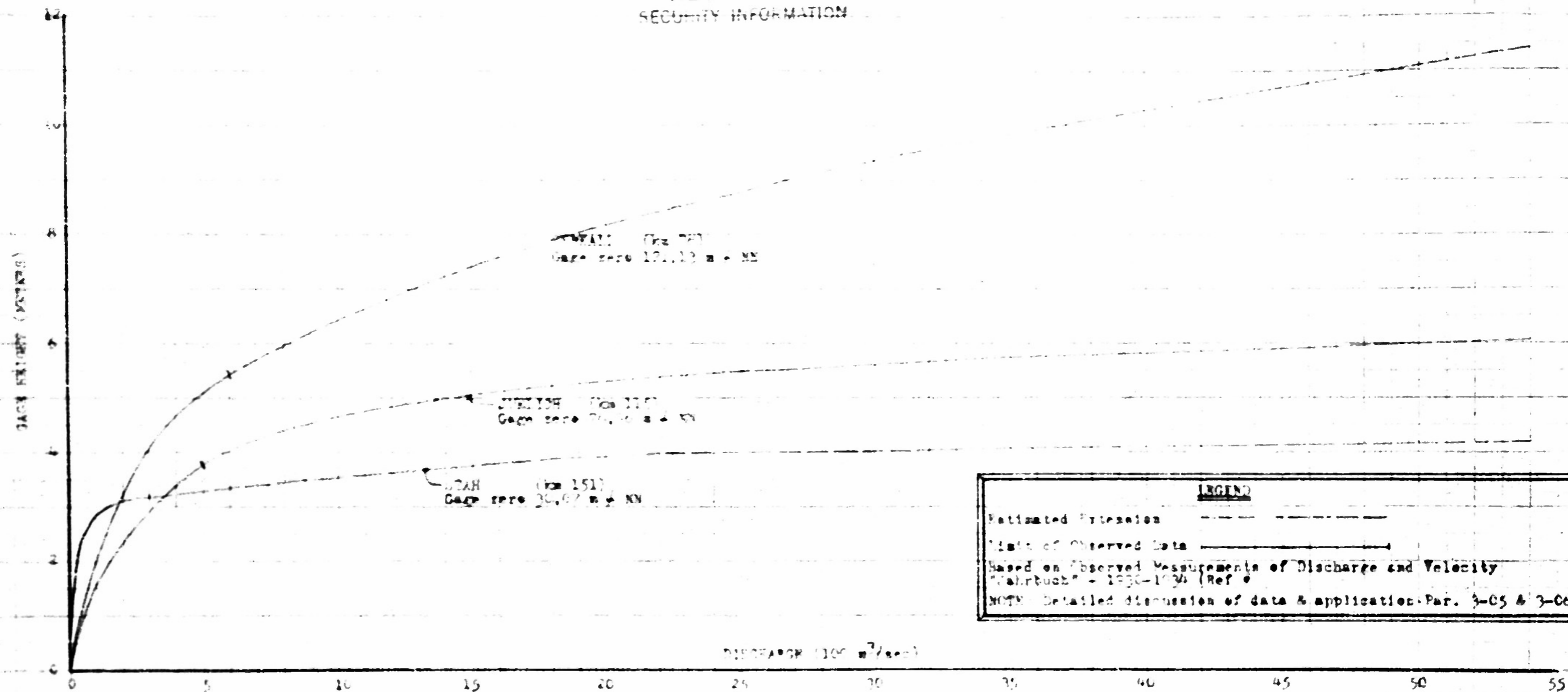
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RUR (ROER) RIVER STAGE, DISCHARGE & VELOCITY MONTHLY VARIATION

MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

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Drawn by: 28

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RUR(ROER) RIVER

DISCHARGE & VELOCITY RATING CURVES

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by JSN Date Oct 52
Drawn by JSN

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LEGEND

Sheet Line 55GS 44H (1:25000)

"Nord de Guerre" Grid Lines

Bridge Sites

Proposed Area See Table 6

Site Serial See Table 6

Scale 1:25000

Serial 34

Serial 34

Serial 47

Serial 37

Serial 35, 16

Jülich
(Jülich)

Rur (River) F

Orsbach

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Q. 1. How does it work?

Am 12/4

Dr. J. C. ...

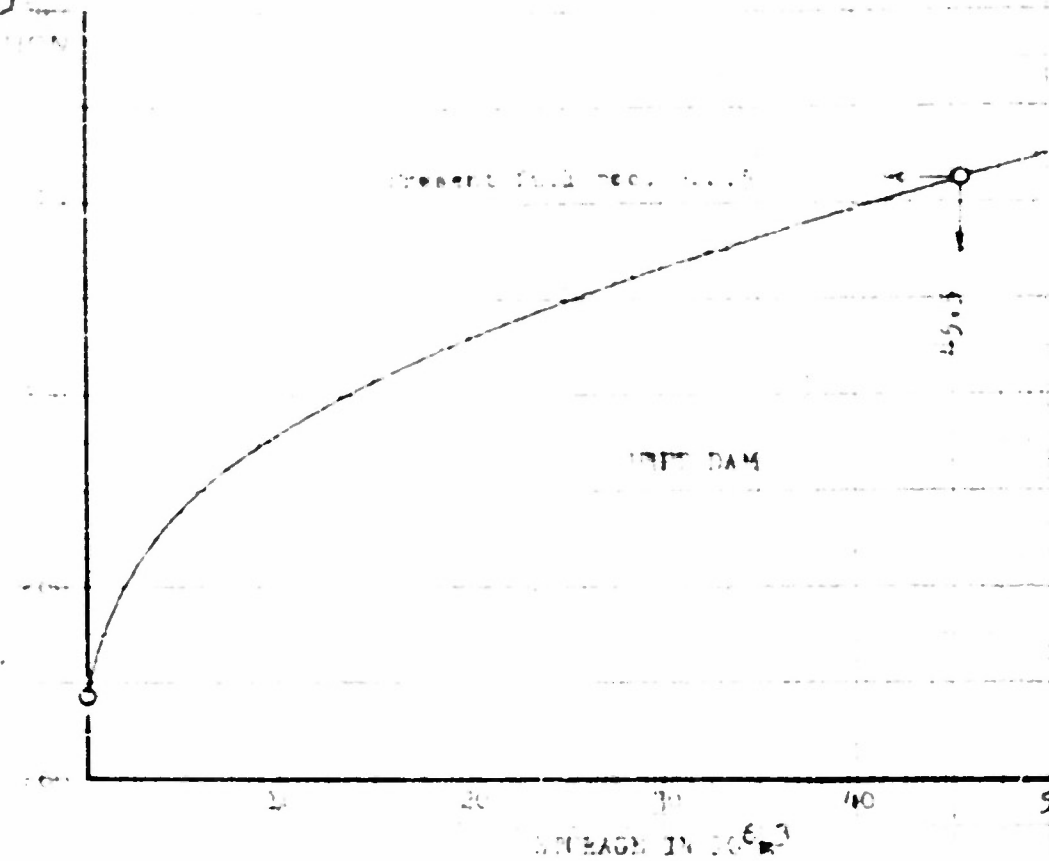
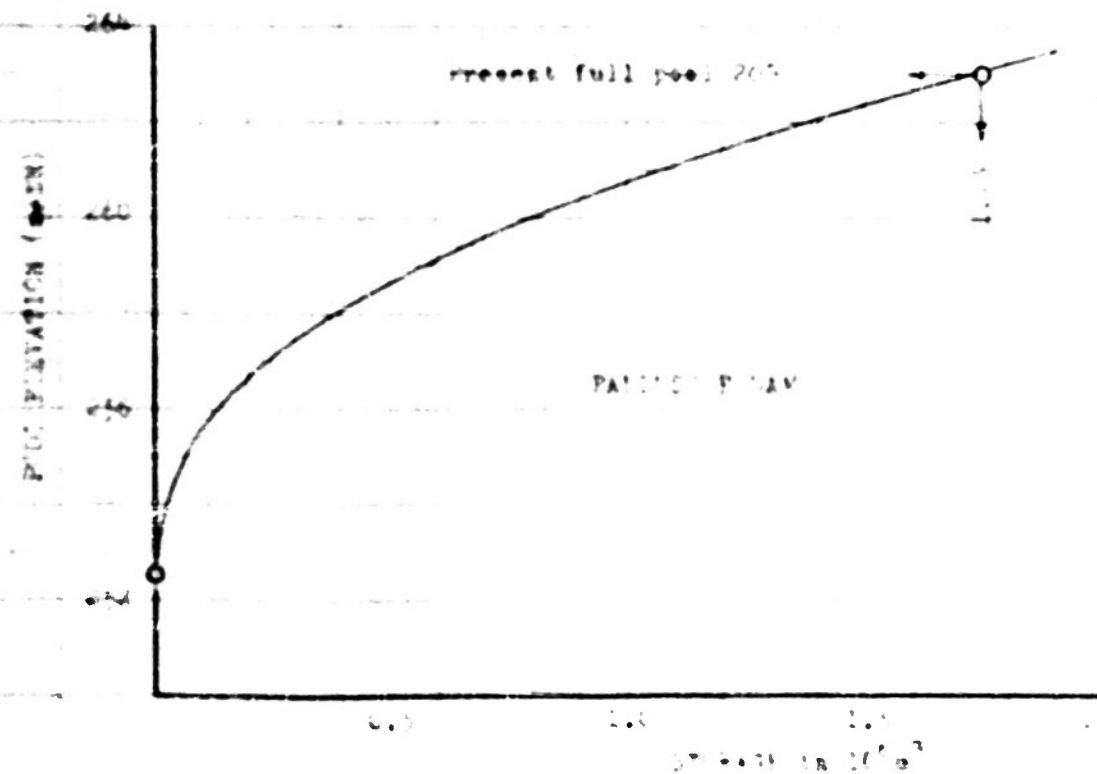
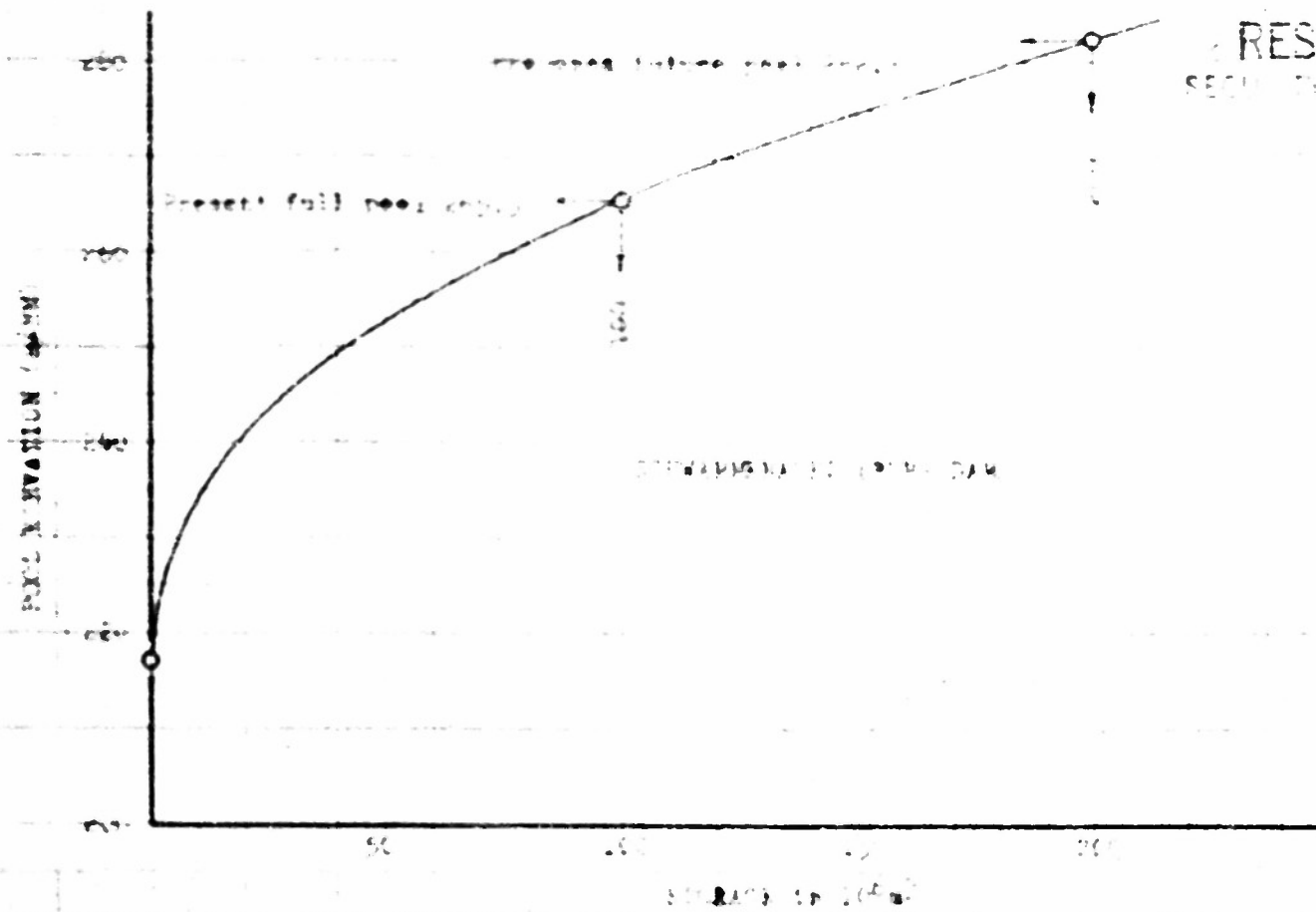
Serial-47

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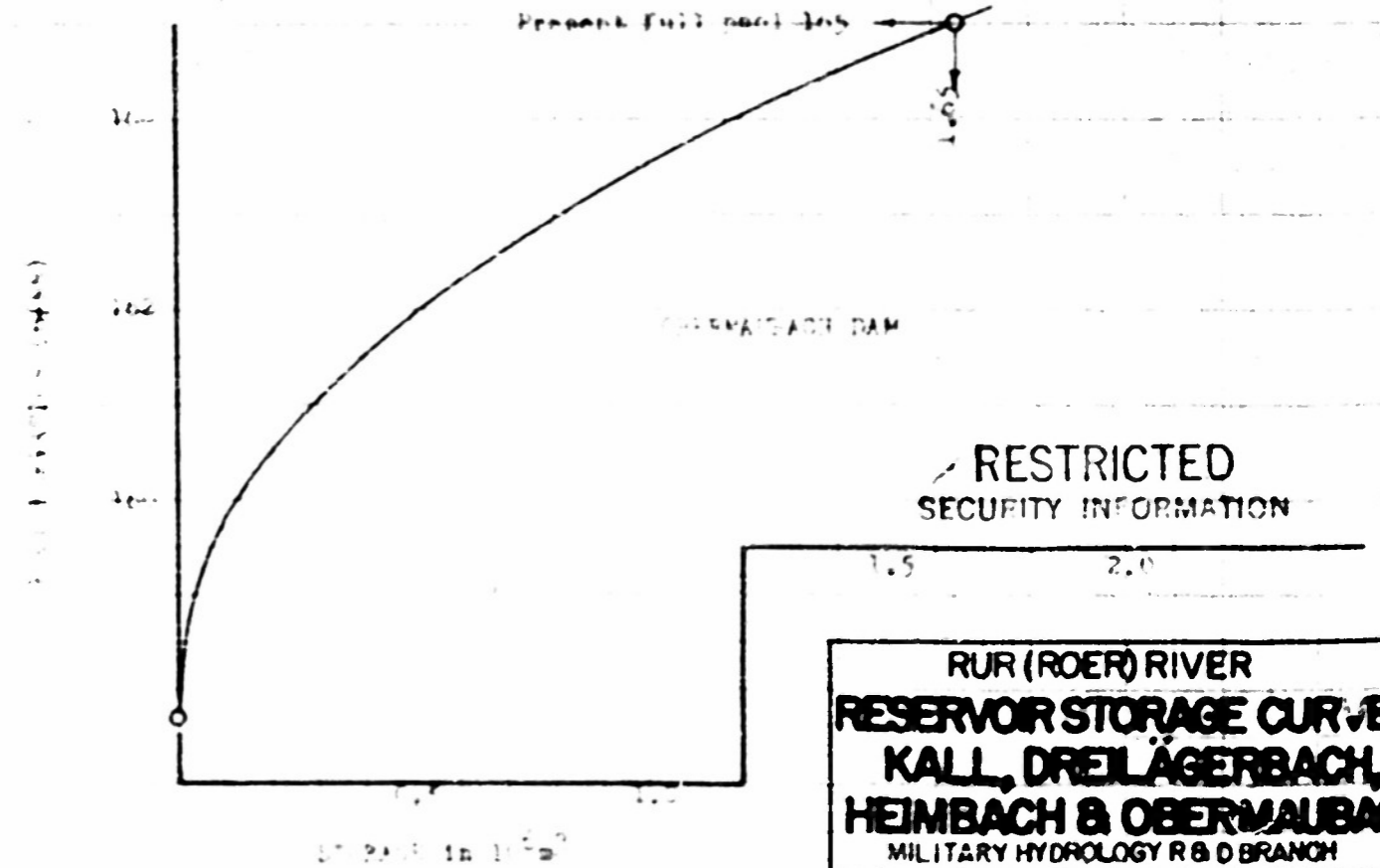
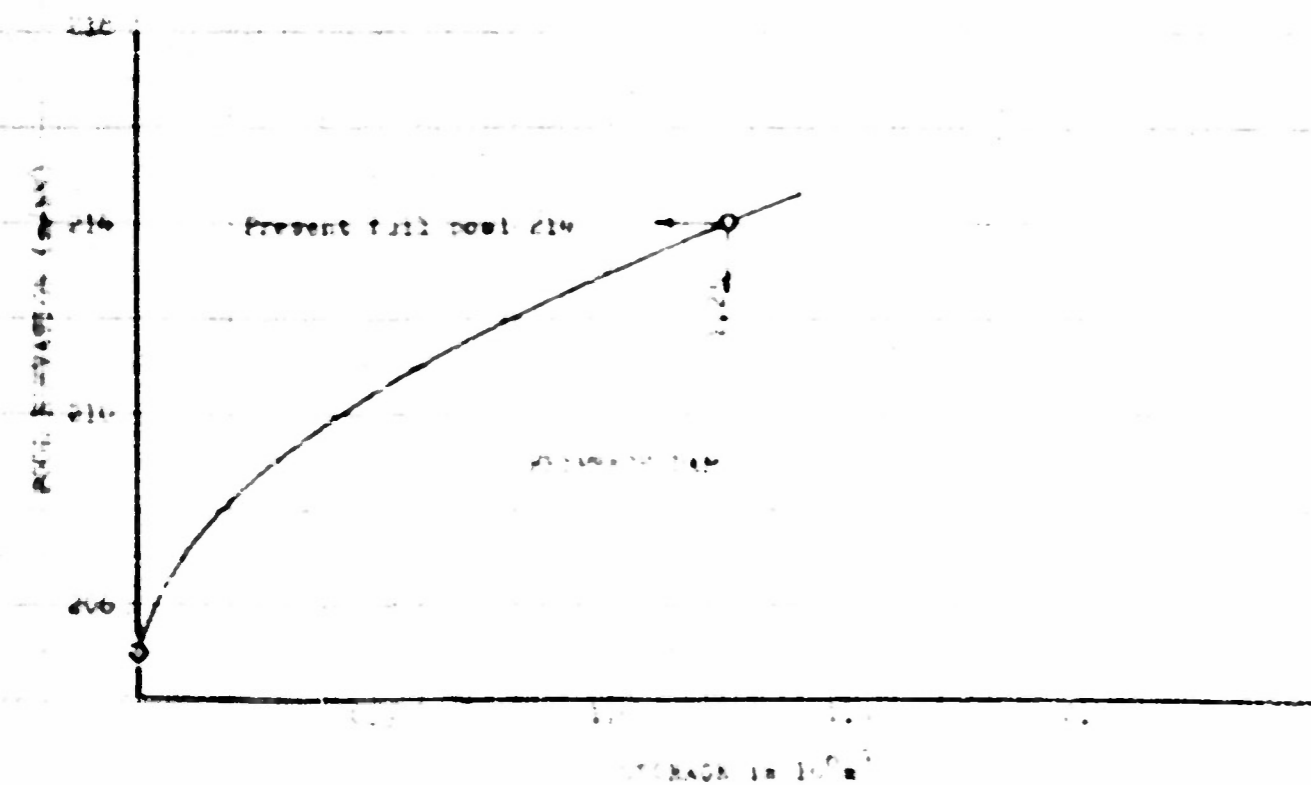
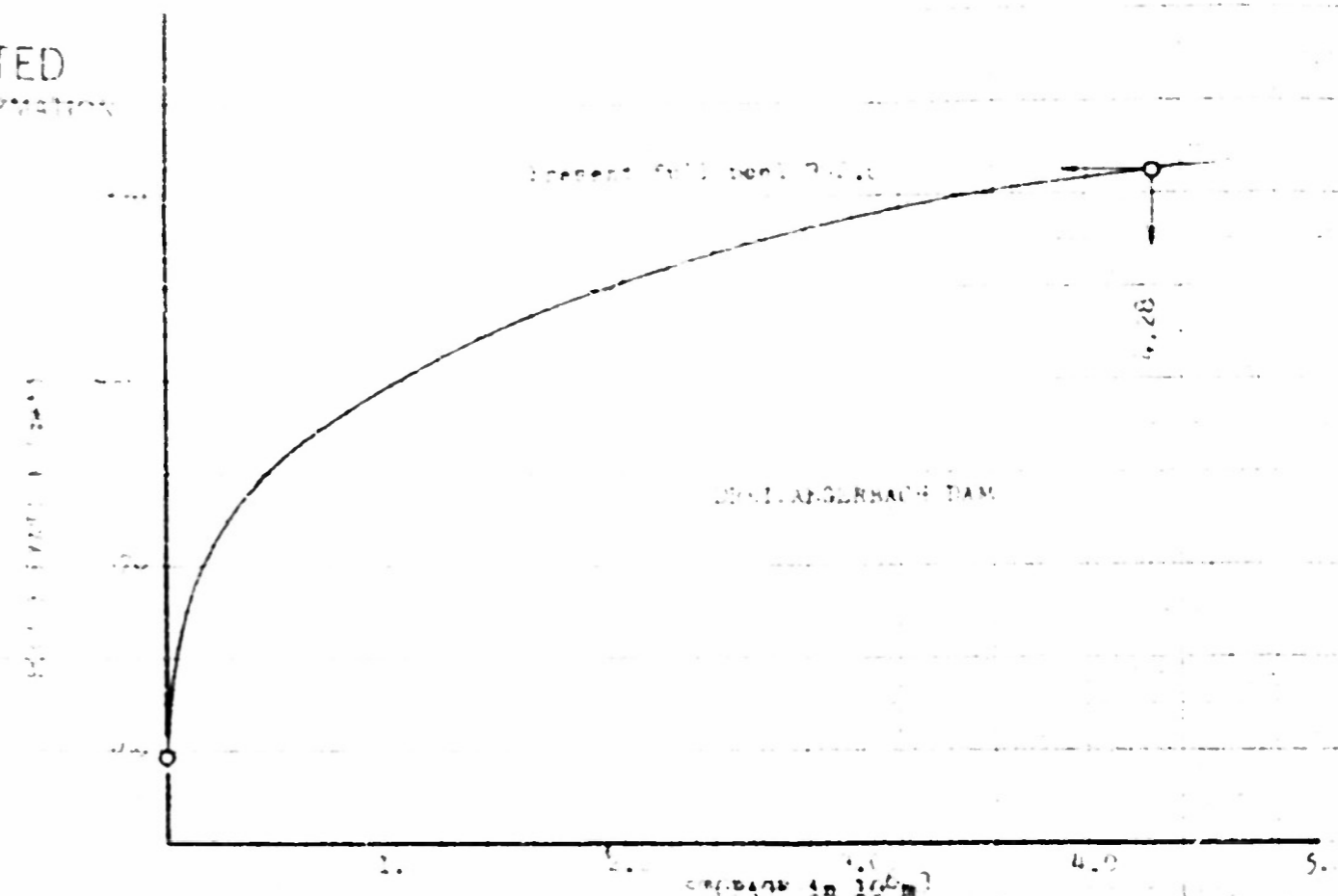
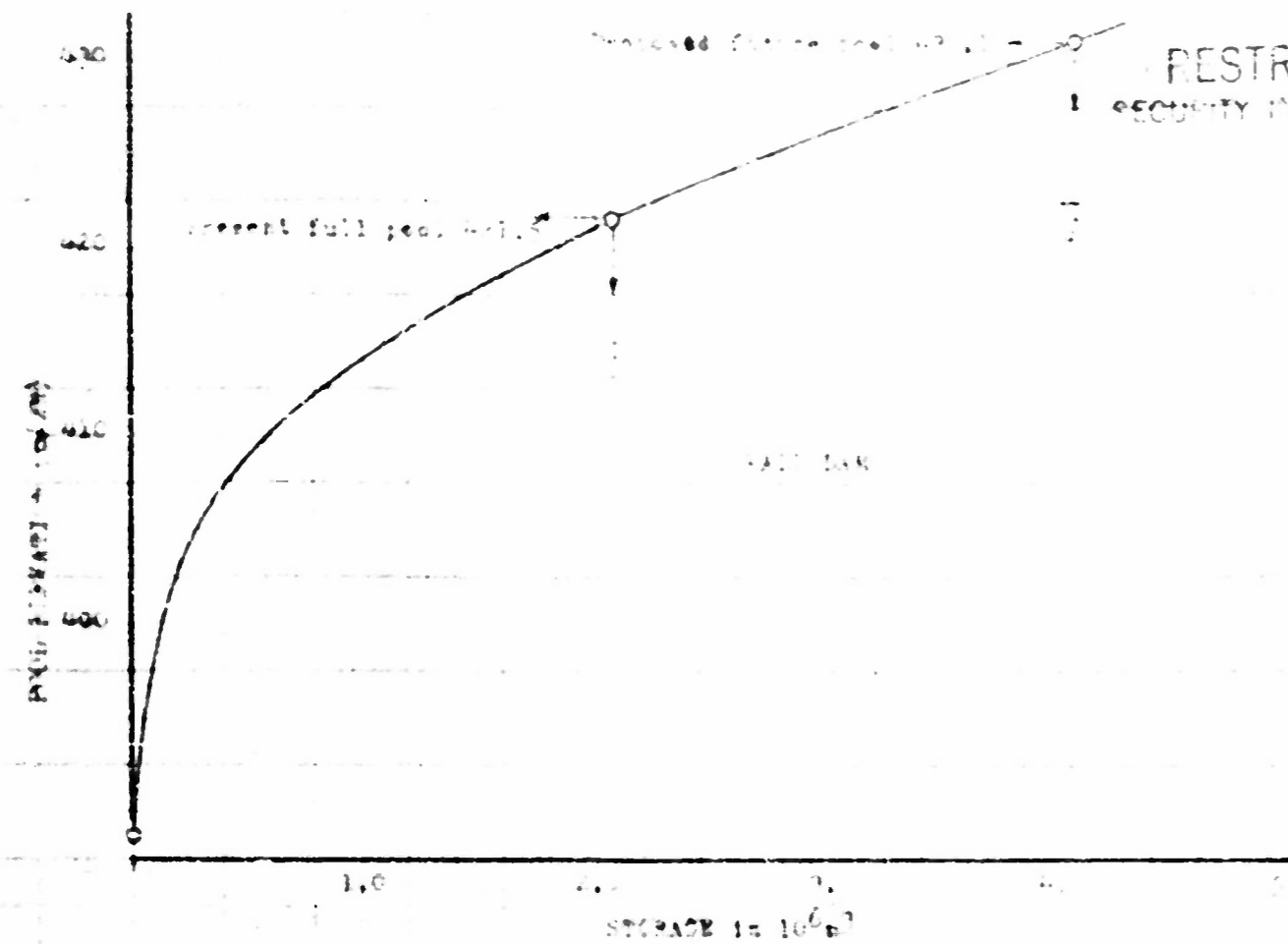
RUR (ROEF) RIVER	
INUNDATION BY	
STILLWATER BARRIERS	
MILITARY HYDROLOGY R & D BRANCH	
WASHINGTON DISTRICT CORPS OF ENGINEERS	
Prepared by	25. Date Oct. 52
Drawn by	25. PLATE 14



These curves were estimated by the method described in para. 4-10b and are based on data cited in technical publications and designated as O.

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RUR (ROER) RIVER
RESERVOIR STORAGE CURVES
RUR, URFT &
PAULUSHOF
MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by Date
Drawn by



NOTE: Storage curves were estimated by the method described in Memorandum 1-510 and are based on data cited in technical illustrations and designated as O.

RUR (ROER) RIVER
RESERVOIR STORAGE CURVES
KALL, DREILÄGERBACH,
HEIMACH & OBERMAUBACH
MILITARY HYDROLOGY R & O BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by _____ Date 6/1/53
Drawn by _____

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Life-Saving 215 & 216 River
URFT Dam Flood Discharge

For Low Velocity
Discharge

See Table 7.
The graph shows the
flood wave of the URFT Dam
flood wave of the URFT Dam
flood wave of the URFT Dam
flood wave of the URFT Dam

See Table 7.

See Table 7.

See Table 7.

See Table 7.

See Table 7.

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See Table 7.

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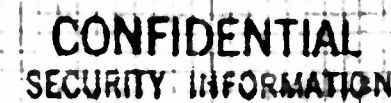
RUR(ROER) RIVER
HYDROGRAPHS
MAJOR FLOOD WAVE
URFT & RUR DAM BREACH

MILITARY HYDROLOGY R&D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by _____ Date _____
Drawn by _____

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**RUR (ROER) RIVER
HYDROGRAPHS
MAJOR FLOOD WAVE
KALL & DREILAGEBACH
MILITARY HYDROLOGY RES. BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by F. H. S. Date 10-1-50
Drawn by 1-1-50**

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FIG. 1. (a) - Flood Hydrograph, 1944-45
1.2 Full Scale - 1000 cfs
FIG. 1. (b) - Flood Hydrograph, 1944-45
1.2 Full Scale - 1000 cfs

1.2 Full Scale - 1000 cfs

1.2 Full Scale - 1000 cfs

20

20

17

17

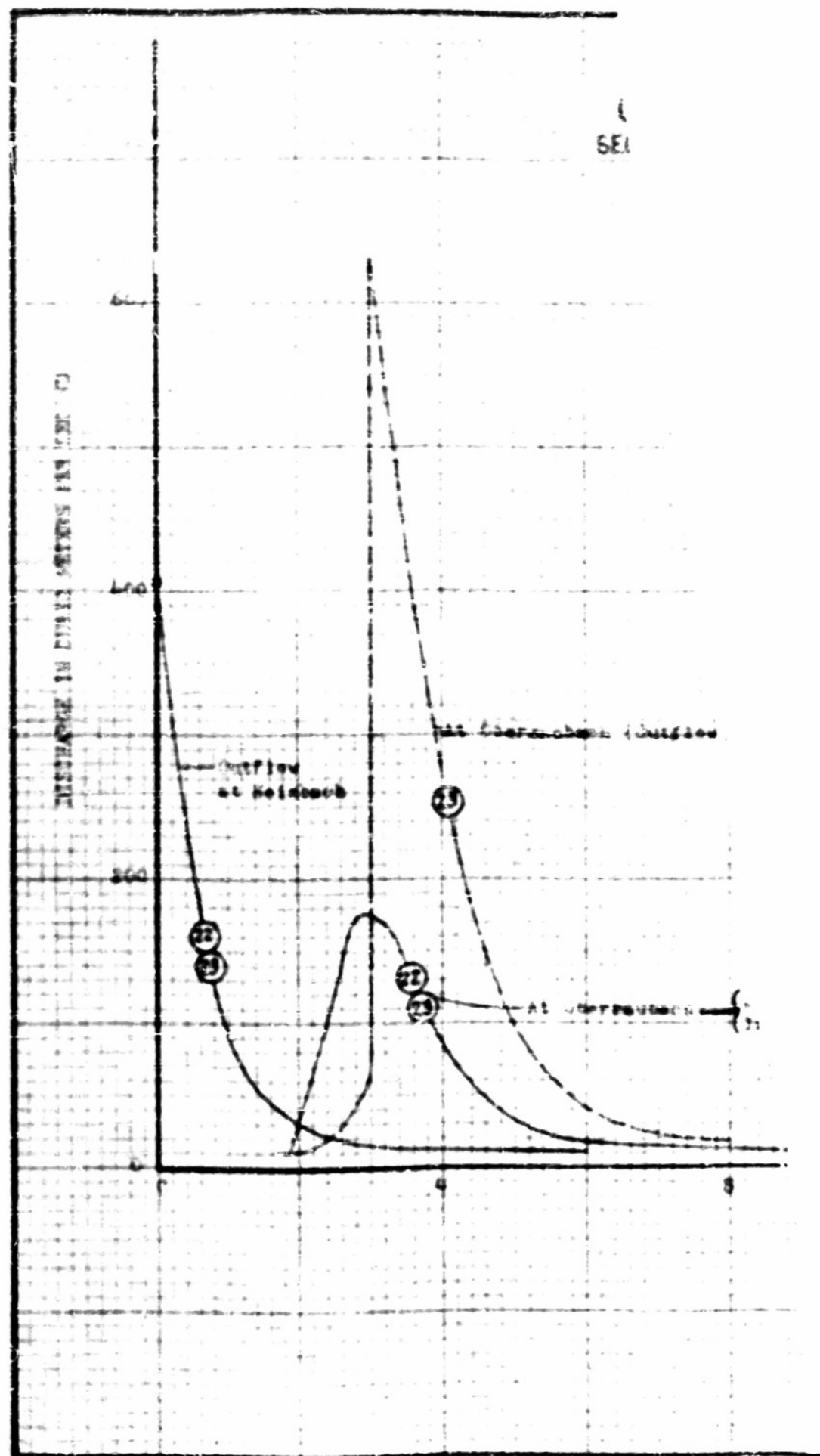
1.2 Full Scale - 1000 cfs

1.2 Full Scale - 1000 cfs

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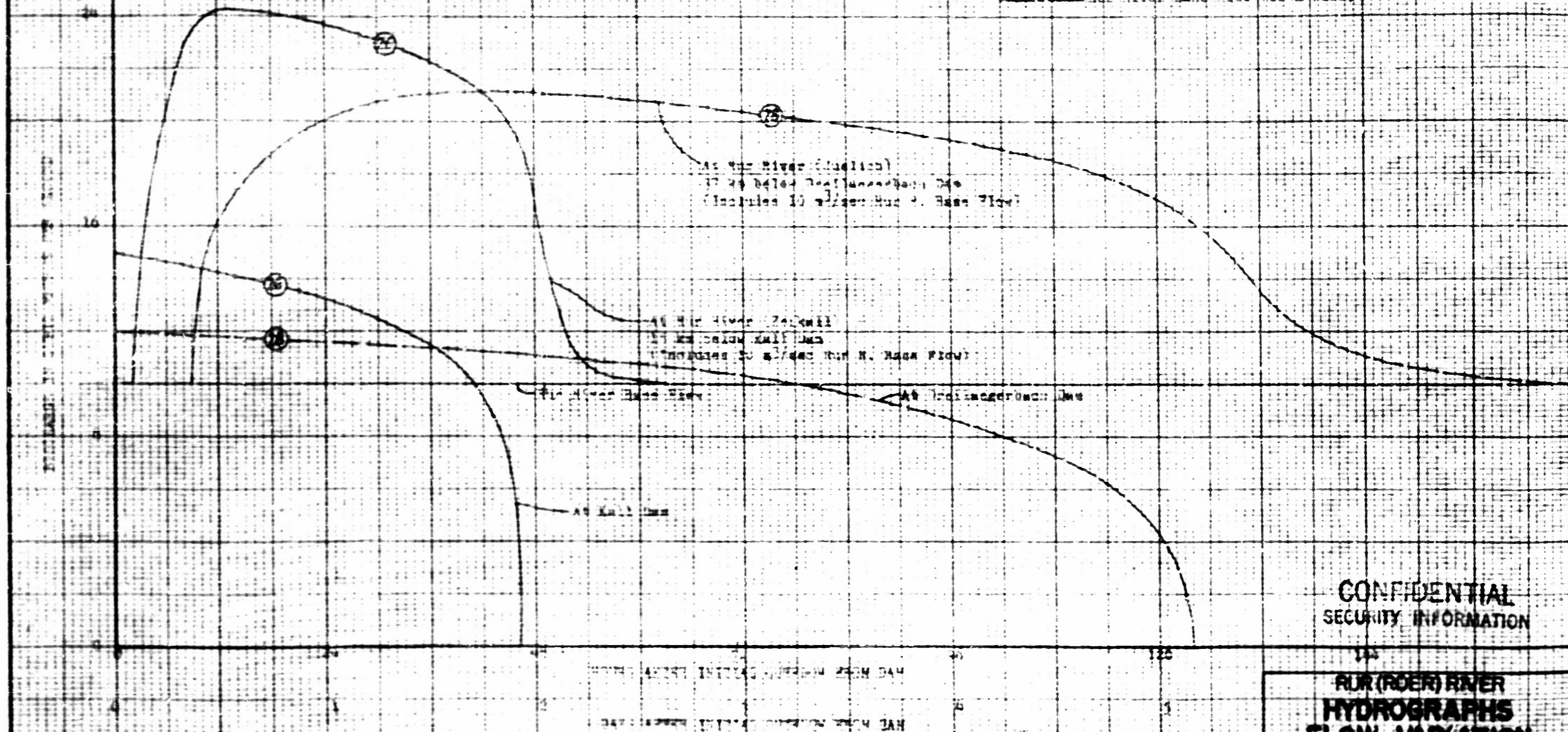
RUR (ROER) RIVER
HYDROGRAPHIS
FLOW VARIATION
URFT & RUR DAMS

MILITARY HYDROLOGICAL BRANCH
Prepared by: [Signature]
Order by: [Signature]



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- Legend:
- Flood No. 25 - Kall Dam, Normal Height
 - Flood No. 25 - Drelagerbach Dam, Normal Height, Full Pool
 - Run River Hand View (10 m. Head)



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**RUR (ROER) RIVER
HYDROGRAPHS
FLOW VARIATION
KALL & DRELAGERBACH**

MILITARY HYDROLOGY REGIMENT
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by: J. F. L. Date: 1/2/55
Drawn by: J. F. L.

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EXHIBIT A

DESCRIPTION OF WATERCOURSE AND CONTROL STRUCTURES

THE RHEIN (ROER) AND URFT RIVERS*

	<u>Page</u>
I Short Description of the Watercourse	A-1
II Peacetime Regulation and Utilization of Discharge	A-1
III Wartime Changes in Discharge	A-2

Tables: Description of Watercourse - 8 pages

List of Weirs and Dams - 4 pages

*Abstracted and translated by Military Hydrology Branch, Washington District, Corps of Engineers, from "Stromgebiet des Rhein, Einwirkung auf die Wasserfuehrung" (Rhine River Basin, Influence of Flow). Military Geography (Mil-Geo) Training Manual H. Dv. g. 34a. General Staff of German Army Section VI, Munster 1939.

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12. THE RUR (ROER) AND URFT RIVERS

Stretch of river from the source to confluence
with the Maas (Meuse) River.

I. Short Description of the Watercourse.

The Rur (Roer) River rises in the Hocheifel (Hohes Venn) and flows as far as Kreuzau south of Dueren in mountain country, from there to Juelich in hilly country, and then to the German-Netherlands border in flat country. At Roermond in Dutch territory it empties into the Maas (Meuse) River. In the mountain country at low and mean water levels, wherever the Rur River is not dammed, it constitutes no obstacle because of its low discharge; the same is true in the hills and in the flat country as far as Linnich, because water is withdrawn into lateral industrial channels. Downstream from here to the border, mean water (MW) does not reach more than about 1m depth. The current velocity is considerable, since the fall amounts to 0.29% declining to 0.16%. At high water (HW) in the spring, the Rur River is a considerable obstacle because of its rushing current and bank overflows. Water depths at summer HW are at Zerkall 1.48m (70.9 m³/sec), at Juelich 1.75m (130 m³/sec), and at Stah 3.10m (140 m³/sec); highest high water (HHW) at Zerkall is above 5.0m (567 m³/sec), at Juelich 3.80m (400-500 m³/sec) and at Stah 3.75m (400-500 m³/sec). The larger tributaries are the Urft, the Kall, the Inde and the Wurm Rivers. At the mouth, the high water of the Maas River under certain circumstances, backs up 15 km into the Rur River. The normal length of the retention pond of the Maas River lock at Roermond is about 7.5 km.

II. Peacetime Regulation and Utilization
of Discharge

The Rur River and its tributaries are not navigable — except for a short stretch in the retention basin of the Maas River at the mouth at Roermond harbor. The river is used for domestic and drinking water in the industrial region on the left bank of the Rhine River (Rur, Inde and Wurm River Basins, and the Aachen local district). The Urft Dam (No. 189) with 45.5 million m³ storage capacity and the Rur Dam (No. 251) with 100 million m³ storage capacity impound the flood water and release uniformly about 9 m³/sec into the Rur River for power generation. In the equalizing basins at Heimbach (No. 242) with 1.25 million m³ capacity and at Obermaubach (No. 234) with 1.5 million m³ capacity, the water is again impounded and is supplied according to need to the downstream industries. In industrial canals (ponds) the water flows on both sides of the Rur River to the plants. Waste water returns to the channels and thus to the Rur River.

Independent of this water storage dam system, are the Kall Dam (No. 232) with 2.1 million m³ capacity, and the Dreilaegerbach Dam (No. 66). The latter has a 4.3 million m³ capacity and is connected with the former by means of a tunnel. These reservoirs supply the Aachen local district with industrial and drinking water. The fore-basin at Paulushof, (No. 394), has no practical significance. Building of additional water storage dams is planned (1939).

*NOTE: See plate 2 for geographical locations.

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III. Wartime Changes in Discharge

1. Utilization for Warfare.

a. Reinforcement as an Obstacle.

The water supply of the reservoirs can be used to raise the level of the Rur River so high that it will have high water for a long time and will overflow its banks in places and become unfordable. The extent of the high water will depend on the available water supply in the reservoirs and the inflow from the tributary streams at the time. The reservoirs are generally only about 1/2 full from August to December, 4/5 full from April to June, and in the other months filled to 2/3 of their capacity. Only after a heavy rain or in time of melting snow do the dams run over. Since the Rur has a great fall and at high water levels a great velocity, fording becomes difficult even at a depth of 1.50m. Such a depth exists at summer high water with a discharge of 75 m³/sec at Zerkall (mouth of the Kall River), river km 73.3; at a discharge of 100 m³/sec at Juelich, river km 115; and even at 30 m³/sec at Stah, river km 154. Therefore, to produce a continuous water obstacle from the reservoirs to the Maas River a supply of 100 m³/sec from the basins would be sufficient. The total volume of the reservoirs named amounts to about 160 million m³. If half of this (80 million m³) is available, then the flow of 100 m³/sec would last about 9-1/2 days. With this discharge, bank overflows would occur over practically the entire reach. The depth in the river would then be 2.0m at Zerkall, 1.50m at Juelich, and 2.70m at Stah. The flood will last longer if the reservoirs have been completely filled previously by well-timed closure of the outlets. The effect can be increased by closing the industrial channels or by short diversions into the Rur River and by barriers at the bridges. To release a discharge of about 100 m³/sec from the basins, the following is necessary: release of about 22 m³/sec into the Rur River from the fully feathered turbines of the Heimbach power plant of the Urft Dam (this water flows into the Heimbach Equalizing basin below the Rur Dam at Schwarzenauel). The remaining water (78 m³/sec) will be obtained from the Rur Dam which can furnish 90 m³/sec.

The Kall Dam and the Dredlagerbach Dam will then have to be utilized only for increasing the duration of the flood. The equalizing basins at Heimbach and Obermaubach, and sometimes also the 4m high sluice-gate on the Rur Dam at Schwarzenauel, can be opened suddenly in order to produce a short but high flood wave (500 m³/sec) after complete filling of the basins. The effect of such a wave could be catastrophic. If the sudden release from the full equalizing basin at Obermaubach is synchronized to follow the entry of the flood wave from the basin at Heimbach, then the effect will be further increased. Such a wave lasts only a few hours, but can desolate the Rur valley entirely.

The foregoing measures can be executed only if the dams are not already in enemy hands, or if reclosing the opened discharges is prevented on abandonment of the dams (jamming of valves, or blasting of conduits).

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By blowing the concrete walls of the Rur and Urft Dams (possible in the inspection galleries), considerably greater destructive waves occur which would destroy everything in the densely industrialized valleys as far as the Meuse River and on into Holland, endangering the population. The demolition of the Kall and Drailagerbach Dams would cut off the drinking water supply to the entire Aachen district.

This threat (as described above) presented by the full reservoirs in enemy hands can only be obviated by timely release of water from the dams.*

b. Removal as an Obstacle.

The obstacle represented by the dammed stretches can be eliminated by releasing the water from the storage dams and basins. With a strong natural discharge in the Rur River by cutting off all discharge outlets of the valley dams and basins, the water level of the Rur River can be lowered for a time depending on weather conditions.

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*translator's note: i.e., prior to capture by the enemy.

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DESCRIPTION OF WATERCOURSE

Rur & Urft
Page 1 of 8 pages

River km	Location	Map Ref. #	Aval. Width	MVS				MVS				High Water Level (Hochw.)				Stream Bed Data	Banks, levees, Dikes, etc.	Remarks
				Aver. Depth	Max. Depth	Disch. m ³ /sec	Max. Vol.	Aver. Depth	Max. Depth	Disch. m ³ /sec	Max. Vol.	Elev. m-AS	Disch. m ³ /sec	Max. Vol.	Elev. m-AS			
0 to 12.8	1100 m east of Monte Rigi in Belgium to the German border		3.0 to 5.0	0.4	500.0	500.2	0.120	0.2	500.4	0.360	0.3	501.4	6.3	1.5	501.6	Upper course in the Rhenes Venn. River bed firm bottom, clayey in part.	Banks marshy for the most part.	
12.8 to 40.7	Border between Belgium and Germany to north of Eistrup, end of pond of the Pauluscher fore-basin		10.0	0.6	275.0	275.4	1.2	0.3	275.6	2.40	0.4	276.6	58	2.5	277.0	Mountain country River bed rocky, otherwise firm, with detritus.	Banks mostly verti- cal & firm; in the city of Monschau quay walls at both sides; narrow val- ley mostly steep slopes, high water overflows banks except at Monschau.	
40.7 to 44.9	North of Eistrup to the enhancement and dam installation at Pauluscher	394														Mountain country. Adjoining the basin, in which the level is almost always at the normal stage are steep and in part wooded valley slopes.	At km 44.65, mouth of the Urft & km upstream is the Urft dam from which most of the water is conducted to Heimbach by way of the power galler- ies of the Rur (Reer).	

*See River Basin Map (Plate 2)
**See Table 2 for Definition of Terms

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Page 2 of 8 page 1

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reten-
tion
level
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• See River Basin Map (Plate 2)
• See Table 2 for Definition of Terms

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1997 2000 2003 2006 2009 2012 2015 2018 2021 2024 2027 2030 2033 2036 2039 2042 2045 2048 2051 2054 2057 2060 2063 2066 2069 2072 2075 2078 2081 2084 2087 2090 2093 2096 2099 2102 2105 2108 2111 2114 2117 2120 2123 2126 2129 2132 2135 2138 2141 2144 2147 2150 2153 2156 2159 2162 2165 2168 2171 2174 2177 2180 2183 2186 2189 2192 2195 2198 2201 2204 2207 2210 2213 2216 2219 2222 2225 2228 2231 2234 2237 2240 2243 2246 2249 2252 2255 2258 2261 2264 2267 2270 2273 2276 2279 2282 2285 2288 2291 2294 2297 2300 2303 2306 2309 2312 2315 2318 2321 2324 2327 2330 2333 2336 2339 2342 2345 2348 2351 2354 2357 2360 2363 2366 2369 2372 2375 2378 2381 2384 2387 2390 2393 2396 2399 2402 2405 2408 2411 2414 2417 2420 2423 2426 2429 2432 2435 2438 2441 2444 2447 2450 2453 2456 2459 2462 2465 2468 2471 2474 2477 2480 2483 2486 2489 2492 2495 2498 2501 2504 2507 2510 2513 2516 2519 2522 2525 2528 2531 2534 2537 2540 2543 2546 2549 2552 2555 2558 2561 2564 2567 2570 2573 2576 2579 2582 2585 2588 2591 2594 2597 2600 2603 2606 2609 2612 2615 2618 2621 2624 2627 2630 2633 2636 2639 2642 2645 2648 2651 2654 2657 2660 2663 2666 2669 2672 2675 2678 2681 2684 2687 2690 2693 2696 2699 2702 2705 2708 2711 2714 2717 2720 2723 2726 2729 2732 2735 2738 2741 2744 2747 2750 2753 2756 2759 2762 2765 2768 2771 2774 2777 2780 2783 2786 2789 2792 2795 2798 2801 2804 2807 2810 2813 2816 2819 2822 2825 2828 2831 2834 2837 2840 2843 2846 2849 2852 2855 2858 2861 2864 2867 2870 2873 2876 2879 2882 2885 2888 2891 2894 2897 2900 2903 2906 2909 2912 2915 2918 2921 2924 2927 2930 2933 2936 2939 2942 2945 2948 2951 2954 2957 2960 2963 2966 2969 2972 2975 2978 2981 2984 2987 2990 2993 2996 2999 3002 3005 3008 3011 3014 3017 3020 3023 3026 3029 3032 3035 3038 3041 3044 3047 3050 3053 3056 3059 3062 3065 3068 3071 3074 3077 3080 3083 3086 3089 3092 3095 3098 3101 3104 3107 3110 3113 3116 3119 3122 3125 3128 3131 3134 3137 3140 3143 3146 3149 3152 3155 3158 3161 3164 3167 3170 3173 3176 3179 3182 3185 3188 3191 3194 3197 3200 3203 3206 3209 3212 3215 3218 3221 3224 3227 3230 3233 3236 3239 3242 3245 3248 3251 3254 3257 3260 3263 3266 3269 3272 3275 3278 3281 3284 3287 3290 3293 3296 3299 3302 3305 3308 3311 3314 3317 3320 3323 3326 3329 3332 3335 3338 3341 3344 3347 3350 3353 3356 3359 3362 3365 3368 3371 3374 3377 3380 3383 3386 3389 3392 3395 3398 3401 3404 3407 3410 3413 3416 3419 3422 3425 3428 3431 3434 3437 3440 3443 3446 3449 3452 3455 3458 3461 3464 3467 3470 3473 3476 3479 3482 3485 3488 3491 3494 3497 3500 3503 3506 3509 3512 3515 3518 3521 3524 3527 3530 3533 3536 3539 3542 3545 3548 3551 3554 3557 3560 3563 3566 3569 3572 3575 3578 3581 3584 3587 3590 3593 3596 3599 3602 3605 3608 3611 3614 3617 3620 3623 3626 3629 3632 3635 3638 3641 3644 3647 3650 3653 3656 3659 3662 3665 3668 3671 3674 3677 3680 3683 3686 3689 3692 3695 3698 3701 3704 3707 3710 3713 3716 3719 3722 3725 3728 3731 3734 3737 3740 3743 3746 3749 3752 3755 3758 3761 3764 3767 3770 3773 3776 3779 3782 3785 3788 3791 3794 3797 3800 3803 3806 3809 3812 3815 3818 3821 3824 3827 3830 3833 3836 3839 3842 3845 3848 3851 3854 3857 3860 3863 3866 3869 3872 3875 3878 3881 3884 3887 3890 3893 3896 3899 3902 3905 3908 3911 3914 3917 3920 3923 3926 3929 3932 3935 3938 3941 3944 3947 3950 3953 3956 3959 3962 3965 3968 3971 3974 3977 3980 3983 3986 3989 3992 3995 3998 4001 4004 4007 4010 4013 4016 4019 4022 4025 4028 4031 4034 4037 4040 4043 4046 4049 4052 4055 4058 4061 4064 4067 4070 4073 4076 4079 4082 4085 4088 4091 4094 4097 4100 4103 4106 4109 4112 4115 4118 4121 4124 4127 4130 4133 4136 4139 4142 4145 4148 4151 4154 4157 4160 4163 4166 4169 4172 4175 4178 4181 4184 4187 4190 4193 4196 4199 4202 4205 4208 4211 4214 4217 4220 4223 4226 4229 4232 4235 4238 4241 4244 4247 4250 4253 4256 4259 4262 4265 4268 4271 4274 4277 4280 4283 4286 4289 4292 4295 4298 4301 4304 4307 4310 4313 4316 4319 4322 4325 4328 4331 4334 4337 4340 4343 4346 4349 4352 4355 4358 4361 4364 4367 4370 4373 4376 4379 4382 4385 4388 4391 4394 4397 4400 4403 4406 4409 4412 4415 4418 4421 4424 4427 4430 4433 4436 4439 4442 4445 4448 4451

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Plate 2 for definition of Terms

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Station	Location	Lat	Long	Alt	Dist	Time	Temp	Hum	Wind	Dir	Speed	Cloud	Vis	Remarks
119.7	Station Kirchberg RR bridge	50.0	10.0	119.7	10.0	119.7	10.0	119.7	10.0	119.7	10.0	119.7	10.0	Remarks
120.0	Station Kirchberg RR bridge	50.0	10.0	120.0	10.0	120.0	10.0	120.0	10.0	120.0	10.0	120.0	10.0	Remarks

See also Table 1 for definition of terms

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River km	Location	Def.	Av. V. m/s
126.6	Stavitskaya Bridge		
149.0	Orskaya Bridge	12.1.20	

149.0	Orskaya Bridge		
159.7	the German-Dutch Barrier	230	0.1 1.0 2.0

See River Basin Map (Plate 2)
See Table 2 for Definition of Terms

Part 4. Draft
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Levees, etc.	Remarks
very steep, subsoil is col- or over- at dia- 00 m/sec. flood area 1000 m tracholun on the about side.	On the left bank is the indus- trial channel from Lin- nich to Hilferth. At Hil- ferth is the left Nur (Reer) dia.
	Fords in places at low water.

Station	Location	Notes	Remarks
10.0	West of Sutherland		
12.0	West of Sutherland		
14.0	West of Sutherland		
16.0	West of Sutherland		
18.0	West of Sutherland		
20.0	West of Sutherland		
22.0	West of Sutherland		
24.0	West of Sutherland		
26.0	West of Sutherland		
28.0	West of Sutherland		
30.0	West of Sutherland		
32.0	West of Sutherland		
34.0	West of Sutherland		
36.0	West of Sutherland		
38.0	West of Sutherland		
40.0	West of Sutherland		
42.0	West of Sutherland		
44.0	West of Sutherland		
46.0	West of Sutherland		
48.0	West of Sutherland		
50.0	West of Sutherland		
52.0	West of Sutherland		
54.0	West of Sutherland		
56.0	West of Sutherland		
58.0	West of Sutherland		
60.0	West of Sutherland		
62.0	West of Sutherland		
64.0	West of Sutherland		
66.0	West of Sutherland		
68.0	West of Sutherland		
70.0	West of Sutherland		
72.0	West of Sutherland		
74.0	West of Sutherland		
76.0	West of Sutherland		
78.0	West of Sutherland		
80.0	West of Sutherland		
82.0	West of Sutherland		
84.0	West of Sutherland		
86.0	West of Sutherland		
88.0	West of Sutherland		
90.0	West of Sutherland		
92.0	West of Sutherland		
94.0	West of Sutherland		
96.0	West of Sutherland		
98.0	West of Sutherland		
100.0	West of Sutherland		

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River	Location	Notes	Remarks
36.75	Point of Descent (mouth of the left)		
37.0	End of pond of the left dam, about 500 m west of the station		The valley is somewhat irregular, irregular, the valley of the left as far as the station is fairly level, in some places level of the station, the average of the banks
37.0	End of pond of the left dam		
38.0	to the dam wall	Planned retention level 200.00	
38.65	Dam wall		End area of the left dam. Adjoining retention levels are steep wooded and in part rocky slopes. No roads of vehicular access to the dam.
38.65	to		Capacity 45.5 mil. m. From the northernmost angle of the retention basin, the tunnel (2 km long) to the Heinsbach power plant branches off (No. 180).
38.65	to		
38.65	mouth into the right of Paulushef.	bed of the left dam 200.00	Adjoining retention water levels are steep wooded slopes. This stretch is flooded by the Paulushef formation the level of which is 206.0 m (No. 304).

*See River Basin Map (plate 1)
*See Table 2 for Definition of Terms
(1) As transcribed from original

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Rur 4 Urft
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Place River km	Obj. No.	Installation Name & Purpose	A. Length of head B. Initial above sea level C. Depth	Type of structure & Dimensions A. Lock B. Dam C. Spillway	Effect: A. Fully closed B. Fully open C. Effect of A & B	Remarks
a. Below dam to the left b. River km 50.15 of the Urft, tributary of the Rur (Heer, mouth at km 50.15 of the Urft, km 50.15 of the Rur)	106	a. Urft reservoir dam b. Power generation, regulation of discharge	a. 1.0 km b. 1.0 m c. 1.0 m depth at the dam d. 1.0 m depth at the dam e. 1.0 m depth at the dam f. 1.0 m depth at the dam g. 1.0 m depth at the dam h. 1.0 m depth at the dam i. 1.0 m depth at the dam j. 1.0 m depth at the dam k. 1.0 m depth at the dam l. 1.0 m depth at the dam m. 1.0 m depth at the dam n. 1.0 m depth at the dam o. 1.0 m depth at the dam p. 1.0 m depth at the dam q. 1.0 m depth at the dam r. 1.0 m depth at the dam s. 1.0 m depth at the dam t. 1.0 m depth at the dam u. 1.0 m depth at the dam v. 1.0 m depth at the dam w. 1.0 m depth at the dam x. 1.0 m depth at the dam y. 1.0 m depth at the dam z. 1.0 m depth at the dam	a. Curved wall of masonry, 100 m long, 5.15 m wide, 100 m wide at the bottom, bottom outlet 4 pipes, capacity 30 m ³ /sec to the Urft, in the galleries 2 pipes 1.5 m diameter, capacity 30 m ³ /sec to the Heimbach power plant on the Rur (Heer, 180). b. Highway bridge, Class II, 1.20 m, 2.5 m and 1.45 m.	a. Filling to overflow b. Emptying c. Consequences of (a) Power plant stops, lack of water for the Duren industries. The Urft and the Rur cease to be obstacles below dam. Consequences of (b): Duren emptying, Urft and Rur obstacle effect increased, discharge 60 m ³ /sec. After emptying, the basin and river are no obstacle. For emptying and refilling time, see Item 4.	With regard to Item 6b, On blasting of the full dam in the accessible discharge galleries, catastrophe fled as for as the Meuse. Arrival of the flood wave at the German frontier is about 20 hours. Destruction of all cities and crossings in the river valley, the Heimbach power plant (No. 180) (8 turbines, 13,400 kw) and the Juelich gas pipe line.
a. Fore dam at Heimbach b. Urft	107	a. Heimbach fore-dam b. Relief for unloading c. Relief for unloading d. Relief for unloading e. Relief for unloading f. Relief for unloading g. Relief for unloading h. Relief for unloading i. Relief for unloading j. Relief for unloading k. Relief for unloading l. Relief for unloading m. Relief for unloading n. Relief for unloading o. Relief for unloading p. Relief for unloading q. Relief for unloading r. Relief for unloading s. Relief for unloading t. Relief for unloading u. Relief for unloading v. Relief for unloading w. Relief for unloading x. Relief for unloading y. Relief for unloading z. Relief for unloading	a. 1.0 km b. 1.0 m c. 1.0 m d. 1.0 m e. 1.0 m f. 1.0 m g. 1.0 m h. 1.0 m i. 1.0 m j. 1.0 m k. 1.0 m l. 1.0 m m. 1.0 m n. 1.0 m o. 1.0 m p. 1.0 m q. 1.0 m r. 1.0 m s. 1.0 m t. 1.0 m u. 1.0 m v. 1.0 m w. 1.0 m x. 1.0 m y. 1.0 m z. 1.0 m	a. Earth embankment with 4 flood openings at 1.0 m, each 5 m long, and 1 shutter opening at 1.0 m, 5 m long, bottom outlet 1.5 x 1.0. b. Highway bridge, Class II, 0.75 m, 3.0 m and 0.75 m.	a. Filled: local obstacle. Emptying: no obstacle.	

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LIST OF DAMS AND BARS

Rur & Urft
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Place	No.	Installation	A. Length of Dam	B. Altitude (Above Sea Level)	C. Discharge Capacity	Type of Structure & Dimensions	Effect	Remarks
1. Schwanenau west of Hoesfeld	1	a. Rur reservoir dam at Schwanenau. b. Regulation of discharge, power generation, flood protection.	a. 17.7 m. b. Crown of dam 420.0 m. Flood stillway 265.5 m wide. - 17 to 650 m. c. 50 m at the dam Length 100 m. duration of emptying 14 days. duration of refilling 14 years.			a. Lock b. Dam c. Breasting d. Earth embankment with concrete and steel core, 350 m long, width of crown 10 m, width at bottom as much as 200.05 m, with bottom discharge galleries outside the embankment, with gate as headwater side, 5.0 x 4.0 m, tailwater tubular closures 2.0 m diameter, 1.5 m diameter and 2.0 m diameter. Discharge 90 m ³ /sec. In the embankment are inspection galleries 2.0 x 1.2 m and drainage galleries. Flood channel is cut off by shutters at 261.50 m, therefore 4 m below the overflow spillway. e. Railway bridge, Class II, 1.5 m, 6.0 m and 1.5 m.	a. Fully closed b. Fully open c. Effect of A & B d. Filling to overflow. e. Emptying. f. Consequences of (e): Power plant stops. Shortage of water for the Duren industries, if the Urft dam (No. 182) is also closed. The Rur is then an obstacle. Consequences of (b): During emptying the Rur becomes a reinforced obstacle, discharge 90 m ³ /sec, then the emptied basin is no longer obstacle.	With regard to Item 3: Schwanenau dam under construction, to be finished 1937. Planned second improvement: increasing the height of the Schwanenau dam by 18 m. Capacity then will be 200 mill. m ³ . Power plant to begin service in 1939, 1 turbine, 10,000 kw, has the function of a peak load plant. The water from the dam can be used if necessary for filling small obstacles in the Rur valley. With regard to Item 6b: On blasting the dam in the inspection galleries, catastrophic flood as far as the Moselle destruction of the cities of Duren, Linnich, Juelich and Neermond, all bridges as far as the Moselle, destruction of the pipe line at Juelich, flood in the Moselle. On sudden opening of the gates of the flood run-off channel when the dam is completely filled, there is a discharge of 200-250 m ³ /sec (Highwater discharge) for about 7 hours.

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Rur & Urft
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Place River km	Obj. No.	Installation (Name & Purpose)	A. Length of Pond B. Altitude (Above Sea) C. D. Width, Depth	Type of Structure & Dimensions A. Lock B. Dam C. Crossing	Effect: 1. Fully closed 2. Fully opened C. Effect of A & B	Remarks
a. West of Heimbach b. 63.4	242	a. Equalizing basin at Heimbach b. Regulation of the discharge of the Rur	a. 3.4 km b. 1214.0 m c. Up to 170 m d. 9.0 m at the dam Content 1.25 mil. m ³ ; duration of emptying 2 to 3 hours, duration of refilling 4 to 5 days under natural inflow.	a. 18.0 x 5.5 m b. Wall with large shutter opening 18.0 x 5.5 m and automatic steel flaps. In the first pier of the weir is a bottom outlet 1.5 x 0.8 m c. Footbridge 1.25 m	a. Filling to overflow b. Emptying c. Consequences of (a) and (b): No regulation of discharge; Dueren industries without adequate water.	With regard to item 6: On demolition of the structure or sudden dropping of the gates by blasting the operating rods of the filled dam: catastrophic flood wave as far as the Heuse, 400-500 m ³ /sec, tempered somewhat if the Obermaubach retention basin (No. 234) is empty, reinforced if the Obermaubach dam is suddenly opened at the time of entry of the wave. For effect in the Rur valley, see No. 251.
a. North of Kallshroten b. Km 7.4 of the Rur, left tributary of the Rur (south) into the Rur, km 78.3)	232	a. Kall reservoir dam b. Drinking water supply, together with the Dreilagerbach dam (No. 66)	a. 1.0 km b. 1421.50 m c. 250 m d. 31 m at the dam Content 2.1 mil. m ³ ; duration of emptying 2 days, duration of refilling 4 to 6 months.	a. b. Earth embankment with concrete core, bottom outlet of 2 pipes 0.65 m x 1.0 m diameter, and inspection gallery in the embankment. c. Highway bridge, Class I, 8.50 m and 1.0 m wide.	a. Dam runs over b. Dam runs dry c. Consequences of (a) and (b): Run-off into the Kall without damage, drinking water supply in the Aachen local district complicated.	With regard to item 6: On blasting the full dam in the inspection gallery; catastrophic flood in the Kall and Rur valleys from Zerkall to the Heuse, duration 24 hours (No. 251). The flood wave is influenced by the Obermaubach dam (No. 234). The water from the dam can be used if needed for filling small obstacles in the Rur valley.
a. Between Obermaubach and Zerkall b. 87.9	234	a. Obermaubach retention lake b. Regulation of discharge	a. 3.4 km b. 1165.0 m c. 300 m d. 7.33 m at the dam Duration of emptying 4 to 5 hours, duration of refilling 4 to 5 days with natural inflow.	a. b. Earth embankment with clay packing, 2 flaps 18.0 m and 8.0 m, 4 m high, at 161.0 m above sea level, bottom outlet 1.0 x 1.5 m. c. Highway bridge, Class II, 3.40 m and 0.75 m.	a. Dam runs over b. Dam runs dry c. Consequences of (a) and (b): No regulation of discharge. Interference to the water supply of the Dueren industries.	With regard to item 6: On blasting the operating rods of the flaps of the full dam or sudden dropping of the flaps: catastrophic flood wave as far as the Heuse, 500 m ³ /sec, reinforced if the Heimbach dam (No. 242) or the Kall dam (No. 65) are so destroyed as to make the flood waves coincide; duration about 20 hours. For effect in the Rur valley, see No. 251. Water from the dam can be used if needed for filling small obstacles in the Rur valley.

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LIST OF DAMS AND DAK

Rur & Urft
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Place River No	Obj. No.	Installation (Name & Purpose)	A. Length of Pond B. Altitude (above sea level) C. Width, Depth D. Content of the dam E. Duration of emptying & refilling	Type of Structure & Dimensions A. Lock B. Dam C. Crossing D. Solid concrete wall with quarry-stone facing, bottom outlet, pipe of 1 m diameter, driving conduit, 1 pipe of 0.50m diameter, inlet from the Fall dam (No. 232).	Effect A. Fully closed B. Fully open C. Effect of A & B D. Dam runs over E. Dam runs dry F. Consequences of (a) and (b): Drinking water supply of the Aachen local district interrupted. Damage considerable.	Remarks
a. Mouth of Rothen b. No 5.7 of the Dralle- Agerbach, tributary of the Vicht, which is a left tributary of the Urft, which is a left tributary of the Rur (mouth into the Rur, No 112.06)	66	a. Dralle-Agerbach reser- voir dam b. Drinking water sup- ply together with the Fall dam (No. 232) for the Aachen local district water- works.	a. 2.0 km b. 43-4.60m c. Up to 450m d. 11.6m at the dam Content 4.7 m ³ . a). dur- ation of emptying 48 days, duration of refilling 8 to 10 months.			With regard to Item B. On blasting the full dam in the outlet galleries catastrophic flood wave through the Vicht, Inde and the Rur to the Moselle, duration a few hours, des- truction of communities and all bridges. Aachen local district without water supply for a long time. The water from the dam cannot be used for filling small obstacle ponds in the Rur valley.

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EXHIBIT 8

ABSTRACTS OF GERMAN TECHNICAL LITERATURE

ON

RUR VALLEY DAMS*

	PAGE
1. General	B-1
2. Schwanenmühl (Rur) Dam	B-2
3. Paulushof Dam	B-5
4. Urft Dam	B-6
5. Hölzbach Weir	B-7
6. Oberndorfbach Weir	B-7
7. Drillingdorfbach Dam	B-8
8. Kall Dam	B-10
9. The Kall Tunnel	B-10
10. Reconstruction of War Damages	B-11

*Abstracted and translated by Military Hydrology Branch, Washington District, Corps of Engineers from German technical literature cited by number in the Bibliography at the end of the text in the main body of the report.

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RUR RIVER DAMS

1. General (References: 5, 6, 11, 12, 13 and 16)*

The flow of the Rur River is regulated and controlled by the following storage dams and hydraulic installations, located on the Rur River and on its tributaries, Urft, Kall and Vicht Rivers.

- a. Schwarzenauel Storage Dam, capacity $100 \times 10^6 \text{ m}^3$,
built 1935-1937
- b. Paulushof Auxiliary Dam
- c. Urft Valley Dam, capacity $45.5 \times 10^6 \text{ m}^3$, built 1904
- d. Heirbach Equalizing Pond, capacity $1.25 \times 10^6 \text{ m}^3$,**
built 1933-35
- e. Obermaubach Equalizing Pond, capacity $1.65 \times 10^6 \text{ m}^3$,**
built 1933-35
- f. Dreilaagerbach Storage Dam, capacity $4.28 \times 10^6 \text{ m}^3$,
built 1909-11
- g. Kall Storage Dam, capacity $2.1 \times 10^6 \text{ m}^3$, built 1934-36

The dams are sometimes called collectively "Eifeltalsperren" (Eifel Valley Dams).

The four installations (Schwarzenauel, Urft, Heirbach, and Obermaubach Dams), located on Rur and Urft Rivers, are interlocked into one hydraulic system, serving to protect the Rur River Basin against damaging flood high water, as well as providing water supply to the industrial region between Lueren-Jualich, during dry summer months.

The Dreilaagerbach and Kall Dams are interlocked in a separate hydraulic system, the primary purpose being to provide the drinking and industrial water supply for the industrial district of Aachen. In addition, their water storage can be exploited independently by the release through Kall and Vicht Rivers to influence the flow of the Rur River.

*Reference numbers listed in the Bibliography of report.

**Capacities quoted in various sources for d. and e. vary from 2.80×10^6 to $3.50 \times 10^6 \text{ m}^3$ for the combined capacities of the two ponds.

The hydrologic conditions of the drainage areas of the Rur and Urft Rivers are characterized by the density of forests and the intensity of precipitation.

The balance sheet of precipitation, runoff, and losses for the watershed of Rur River, including Urft, referred to Heimbach, is outlined in Figs. 1, 2, 3, of Reference 6.

On the average, the precipitation in this area is evenly distributed throughout the year and amounts to 30.7 liter/sec/km² in the period November-April, and 30.0 liter/sec/km² between May-October. The evaporation and percolation losses average 13 liter/sec/km², but vary considerably throughout the year. In the winter period, the losses are very small and in some instances reach a negative magnitude. This is probably due to release of storage from the extensive moorland region in the headwaters, and to the frequent snowfalls. Conversely, during the growing season, due to the large extent of the forested areas, the losses will vary sharply and will reach (usually in July) the highest average value of 28.2 liter/sec/km².

In the winter months, the runoff greatly exceeds the limits of required needs and possible utilization, and damaging floods do then occur. In the summer months, runoff is only 6-7 liter/sec/km², which is not enough to cover the industrial needs of the area.

It was established that approximately 9 m³/sec are needed in the industrial regions below Heimbach. This corresponds to a needed storage capacity of 150×10^6 m³, which is approximately 42 percent of the average yearly inflow. This storage is supplied by the Schwarzenauel and Urft Dams and by the equalizing ponds at Heimbach and Obermaubach, described above.

2. SCHWARZENAUEL (RUR) DAM
(References 5, 6, 7, 8, 11, 12, and 13)

a. Structure of the Dam.

Originally the dam was planned for a storage capacity of 200×10^6 m³. Actually it was built for only 100×10^6 m³, but it may at any time be extended as planned. (See Plate 7 in report and Reference 6).

The dam is a gravity earth dam. This type of dam was chosen because of considerable loam deposits near the selected location of the dam. The quarries which could supply the concrete ingredients, gravel and rubble were lacking. The cross-section of the dam is very diversified as to the structural material used. The most important part of the dam structure is a very solid loam apron, 40 m wide at the bottom, which has the role of sealing the dam.

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The dam is constructed without a rigid core reaching up to the crest as is usually the case of most confined gravity dams. The idea of the planners was to make the structural components of the dam pliable, as far as possible, in order to achieve the greatest possible adjustment of various materials used for the dam construction. They reasoned at the same time that the rigidity of a concrete core would prevent the balancing of the enormous forces inside the dam necessary for settlement of the varieties of structural layers forming the dam.

The only part rigidly connected with the ground is the foundation "socle," which extends 5 m into the solid rock. The rock is supposed to create an impermeable hydraulic water seal. The rock is built up to the normal terrain level. (Reference 12).

An inspection gallery, 1.40 m wide and 2 m high runs through the rock and serves for observations of possible water seepage and for any required repairs of the sealing material.

On the "socle" is a 12 m high concrete wall separated from it entirely by a joint. This joint consists of 0.002 m thick iron sheet between two bituminous layers. (Reference 12). The construction of the joint is such as to permit the shifting, as well as possible tipping, of one body (socle) against the other (core), during the settling of the various materials forming the dam.

Joined to the top of the concrete core is a dividing wall of steel sheet piles consisting of horizontal strips welded longitudinally together out of 12 m long elements. (See Plate 7 and Reference 12). The lock joints of the strips are filled with a bituminous material and the surface of the steel wall covered with bitumen to prevent leakage.

b. Operating Installations of the Dam.

(1) These installations consist of:

(a) Pressure Tunnel - with appropriate closing mechanisms and fittings for utilization of flow for power generation, water supply, etc.

(b) High water Spillway - (See Plate 7 of report and Reference 6).

(2) The pressure tunnel, 360 m long, served as a by-pass conduit during the period of the dam construction. The circular cross-section of the tunnel has 1 m clear diameter.

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The mountain rock, through which the tunnel was drilled, is predominantly solid Devonian schist, with interbedded gray-schale strata of varied thickness. Inside, the tunnel is reinforced by 0.30 m concrete masonry for protection against the natural rock and also to secure the smooth operation of the flow. Along an approximately 50 m long portion of the conduit, where it passes through a greatly depressed clay slate, the protective concrete masonry is reinforced to 0.60 m thickness. In addition, a 0.05 m thick "aricret" coating with steel netting is added in order to avoid possible water seepage, (See Plate 7 of Report).

The entrance to the tunnel is equipped with a gate, 4 m wide, 6 m high, which may be rolled on a sloped track. This is an emergency closure in case the conduit would require inspection while the reservoir is filled.

When open, the gate is located above the reservoir surge and can be lowered into closed position along the track, sloped along the reservoir embankment. The rollers of the gate and the hoisting mechanism are so dimensioned that the closure and opening of the 24-ton heavy gates can be achieved only when the pressure on both sides of the gate are nearly in equilibrium. Consequently, the valves in the downstream portion of the tunnel must be closed and the penstock filled in order to operate the entrance gate.

Two valves, fitted in the upper part of this emergency gate, permit some flow to enter the tunnel when the gates are closed. The opening of the valves is accomplished by a slight pull on the gate pulling cord. The closure is then effected by means of a spring mechanism.

The fine rack with 0.04 m clear width between the bars, has a movable upper part which may be lifted by hooking it on the gate. (Reference 6). The rack weighs 21 tons. By rolling a separate truck on wheels with very wide flanges, the rack may be lifted above the open portion of the gate. By means of either the gate or the rack truck, the rack may be moved in its operating closed position in front of the gate. For operation of the gate and rack, a power-hoisting mechanism and an auxiliary hand mechanism are provided.

On the outlet side, the tunnel ends in a 50 m long concrete plug into which are fitted the pipelines. A 20 m long transition of 3.80 m diameter joins a "Y" piece with 2.0 m and 2.50 m diameter branches equipped with built-in Venturis. (See Plate 7). From the left (a) pipeline, branches another 2.30 m diameter pipe leading to the turbine and powerhouse. All 3 pipelines are equipped with butterfly valves for emergency closure. The two smaller supply lines have the flow controlled by ring valves. Both lines are of 2.00 m diameter.

*Apparently from the 2.30 m diameter pipe

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The outlets have, together, a capacity of $80 \text{ m}^3/\text{sec}$ according to Reference 6. However, Reference 13 cites a capacity of $2 \times 35 \text{ m}^3/\text{sec}$ for the 2 ring valves at 45 m head.

(3) The highwater spillway, constructed as a fixed overflow weir, has a capacity of $450 \text{ m}^3/\text{sec}$ at 1.50 m head on the crest. This capacity is considerably greater than any known floods on the Rur River. The spillway capacity corresponds to $1500 \text{ liter/sec/km}^2$ runoff from the 300 km^2 drainage area of the Rur River at the dam. The drainage area of the Urft River, which is controlled by the Urft Dam, is not included in that runoff value. (Reference 13). At the 267.00 mANN elevation (265.50 mANN normal stage plus 1.50 m head) the surface area of the reservoir is slightly over $5 \times 10^6 \text{ m}^2$. An additional 2 m head, up to 269.00 mANN (the elevation of the crest of the dam) is available.

The spillway has a "hairpin" form, in order to achieve the required overflow crest length of 95.0 m. Adjacent to the overflow, there is a 9.00 m wide weir opening provided with a double tapered gate 5.5 m high. By means of this gate, the $23 \times 10^6 \text{ m}^3$ flood protection storage of the reservoir can be released even when the main outlet of the reservoir would be inoperative because of failure of the tunnel release mechanisms. The gate is automatically opened when the stage reaches 0.50 m above the fixed spillway elevation of 265.5 mANN.

The weir opening has a capacity of $250 \text{ m}^3/\text{sec}$ at a reservoir level of 265.5 mANN (the elevation of the fixed spillway crest). This means that in the rare case in which the stage of the reservoir would rise over normal despite the gate being open, then at 1.50 m head on the spillway, the total discharge would amount to $750 \text{ m}^3/\text{sec}$.

The flow over the spillway and through the weir, passes down a 300 m long chute into the lower pool. A special stilling-basin structure, consisting of 2 basins, (one with +208.00 mANN, and the other with +210.0 mANN bottom elevations) dissipates the energy of the spillway flow. The normal stage of the lower pool has an elevation of 214.00 mANN. The lower stilling basin has an end sill with 3 underwater openings. The combined flow through these openings and over the sill, braked down considerably by the water cushion of the basin may pass without turbulence over the downstream end of the concrete stilling basin. The crest of the basin sill is slightly higher than the bottom of the nearby Heimbach Equalizing Pond.

3. PAULUSHOF AUXILIARY DAM (References 5, 6, 11, 12, and 13)

The 30 km long Schwanenruel Lake is crossed at its upper part by a masonry overflow weir, known as Paulushof Dam.

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It has not any special hydraulic purpose and was supposed to contribute to the natural beauty of the region. (See Plate 8).

However, this auxiliary dam was used extensively during the reconstruction period of the Schwammenauel Dam in the 1945-46 period.

4. URFT DAM (Reference 4).

The drainage area of the Urft River at the location of the dam is 375 km². According to 12 years of observations in the period 1888 to 1899, the mean yearly runoff of this area amounted to 160 million m³, which corresponds approximately to 3 times the storage capacity of the dam.

In figure 1 of Plate 6 of the report and figure 2 of Reference 4, is shown an earth cofferdam which was used for damming of the Urft River during the construction period. This cofferdam diverted at the same time the flow of the Urft to a 140 m long tunnel, to keep the construction location dry. The discharge capacity of this tunnel was approximately 100 m³/sec, corresponding to the maximum recorded HWH. This tunnel is retained in the present structure as a relief outlet as further described.

The dam has a maximum height above the foundation of 58 m, a crest width of 5.5 m, a maximum base width of 50.5 m. The crest length is 226 m, along an arch of 200 m radius. The maximum damming depth over the valley floor (elevation 270.0 mAM) is 52.5 m (elevation 322.5 mAM). The wall is protected on the reservoir side by an earth filled slope, paved on the surface, up to 34 m above the foot of the dam.

The dam structure is constructed out of clay-slate and has a graywacke facing 1 m thick on the reservoir side. On the inside of the graywacke facing, there is a 2.5 cm thick cement-trass coating and a bituminous coating for protection against leakage of water out of the reservoir. At intervals of 2.33 to 2.56 m, we find double drains of 6 cm diameter, made out of clay pipes which join the 15 cm diameter main drain, running along the wall.

The outlet structure of the dam consists of 2 bottom relief outlets constructed as vaulted masonry culverts. In these culverts is built a 60 cm diameter pipeline equipped with a valve operated through shafts which extend in towers to the elevation of the dam crest. The top of the towers are connected to the roadway on the crest of the dam by means of a service bridge.

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The tunnel, which was used during the construction period, serves as an additional relief outlet and permits complete emptying of the reservoir. This tunnel is drilled in the rock and is provided with a concrete plug 24.35 m long through which pass 2 pipes each of 70 cm diameter, and equipped with valves. The tunnel is lined and has a masonry portal at both ends.

The spillway has cascaded steps on its downstream side, and is 90 m long and of particular and unique construction. (See Plate 6 and Reference 4). It consists of a fixed weir of a wave-shaped form in plan view. The crest is at 322.5 mAN which corresponds to the normal stage in the reservoir. The pillars carrying the bridge are 1.00 m wide and the clear width between them is 7.00 m. Some of the bays (number not given), are equipped with a sluice, which has a bottom elevation of 320.00 mAN. The sluices are closed by a gate operated from the service bridge and serve for release of small volumes of water.

The penstock tunnel is 2,800 m long and is pierced through a clay-slate rock. It has a 6.14 m^2 clear cross section area. The gradient of the 2800 m long tunnel towards Heimbach is 2 m. However, the total head brought to the turbines in Heimbach Power plant is approximately 110.00 m.

5. HEIMBACH WEIR (Reference 11).

The Heimbach control structure consists of an 80.0 m long and up to 14.0 m high concrete gravity dam and a movable weir. The weir structure (which is of the same type as the weir at Obermaubach) makes possible a very accurate control of flow for industrial purposes. It also provides an automatic, reliable and fast discharge for floodwater. The weir opening is 18.0 m wide. The closure is a submergible flap-gate hinged at the bottom of the of the opening, which may be dropped to the bottom for the release of high water, or raised to its normal position in which the damming head is 5.50 m. Structurally, the gate is developed as a movable, torsionproof, fishbellied flap, operated by means of a gear mechanism. The complete and fast opening for passing of flood water is achieved by a hydraulic device, operating automatically without any additional power or manual regulation when the stage in the upper pool reaches an established high water stage. (See Plate 8).

Besides the movable weir, a small bottom opening $1.0 \times 1.50 \text{ m}$ in the side pillar provides for releases of small quantities of water and emptying of the pool.

6. OBERMAUBACH WEIR (Reference 11).

The Obermaubach control structure consists of a 200.0 m long earth dam, of 5.0 m mean height plus a movable weir, built on the left side of the dam. (See Plate 8 of report and Figures 7-10 of Reference 11). The movable weir is of the same type as at

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Weirbach and regulates the flow very accurately and provides for quick opening in the case of floods.

The weir opening is 36.0 m wide. The closure is a two-part, submergible flap gate (each part 18.0 m long) hinged at the bottom of the weir opening. Each half of the gate is movable by means of a gear mechanism located in each side pillar. Because of the considerable tension stresses, the structure is built with a fish-bellied cross-section. The height of the gate is 4.0 m.

The complete opening of the gate, by dropping it over the crest of the weir, for passing the high water, can be achieved automatically, without additional power or manual regulation by means of a hydraulic device, which goes into operation at the moment the upper pool reaches the high water stage. Similar to Weirbach Weir, there is a bottom outlet 1.0 x 1.5 m in the left pillar permitting a release of small volumes of water and emptying of the pond.

The water discharge is regulated so that only approximately 3-4 m³/sec are released during the period in which the downstream industrial plants are not in operation. During the operation period, the discharge is increased to at least 7 m³/sec according to the water requirements.

7. DREILAEOGERBACH DAM (References 9, 10, and 15).

The dam was built in the period 1909-1911 and placed into full operation in 1912. It was erected for the purpose of supplying water for the Aachen industrial district. In addition to the city of Aachen, this district contains numerous industrial settlements including the coal mines on the German-Holland border, as well as the Holland cities of Kirchtrath and Vaals. The capacity of the dam is 4.28×10^6 m³.

The natural drainage area of the Dreilaogerbach Dam is only 10.95 km². This was artificially increased in 1918 and 1920 to 22.93 km² by construction of 2 drainage channels, which intercept the flows of numerous small streams in an area of high precipitation. These channels are called the Schleibachhanggraben and Hasselbachhanggraben. The mean yearly precipitation of this drainage area is 1.026 m.

In 1924 to 1926, the drainage area of the Dreilaogerbach Dam was further artificially increased by means of the construction of the so-called "Kall Tunnel" (Kall Stollen). This is a 6,241 m long tunnel, having a clear cross-section area of 5.7 m², and which collects the discharges of the Upper Kall River. The drainage area of the Kall River above the site of the tunnel entrance is 28.6 km² and has a mean yearly precipitation of 1.053 m. The total drainage area of Dreilaogerbach Dam was thus increased to 51.53 km².

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In order to secure the water supply out of the upper Kall River drainage area, it was decided to build a dam — (Kall Dam) near the entrance to the tunnel. This dam was built in the period 1934-1936. The capacity of the Kall Dam is $2.1 \times 10^6 \text{ m}^3$. Provisions are made for future increase of capacity to $4 \times 10^6 \text{ m}^3$. The Drillsgebach Dam is a gravity type dam and is built in an arch form of 350 m radius. The crest is 3 m wide, and 240 m long. The crest elevation is + 393.00 m AD (33.0 m over the floor of the dam). At normal stage, the reservoir area is 0.4 km^2 . (See Plate 9 of the report and Figure 2 of Reference 9).

On the south side, the dam extends over a ridge in the form of a dam wing, along which is located the spillway. The spillway is a Heyon type siphon. It has 5 openings, each 1.42 m wide. The entrance openings have staggered elevations; the difference in elevation between two adjacent openings is 0.01 m. The capacity of the siphon at 0.07 m head is approximately $14 \text{ m}^3/\text{sec}$. The free board of the spillway is 0.33 m while the dam itself has a free board of 0.98 m. In addition to the siphon, the release structure has a 3-part sluice gate 7.10 m wide and 0.60 m high. In an emergency this can carry $7 \text{ m}^3/\text{sec}$ through a chute into the Schloebach. Plate 9 of this report and Figure 3 of Reference 9 show the connection of the dam with the release tower and bottom outlet.

The bottom outlet pipe is 1.0 m diameter. At full head, the discharge capacity is $12 \text{ m}^3/\text{sec}$. Actually, this discharge cannot be achieved on account of faulty construction of the wedge action valve. Dangerous vibration is generated at approximately 0.20 m opening.

The bottom outlet pipe has a cross-connection on the upstream side with an outlet conduit of 0.5 m clearance. The release tower has two operating mechanisms, the upper one being used as long as possible for withdrawal of drinking water.

The negative pressure is measured in the bottom outlet tunnels on the upstream side of the dam, at three locations 8.60 m, 12.20 m and 16.7 m from the foot of the wall. Taking into account the 37.10 m head on the foundation floor at the maximum stage, the negative pressure amounts to 9.0 m, 5.90 m and 5.60 m.

The auxiliary reservoir located above and connected with the main reservoir has a capacity of $70,000 \text{ m}^3$. That auxiliary dam is of the same type as the main dam. A 10.20 m wide spillway is located in the middle of the auxiliary dam.

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8. KALL DAM (References 9, 10, and 15).

This dam has a capacity of $2.1 \times 10^6 \text{ m}^3$. The crest is 5 m wide, 18.0 m long, and 34 m above the bottom of the valley floor. The elevation of the top of the dam is +423.50 m_{AM}. The dam consists of a concrete wall with a loam core on the reservoir side. Gravel fill is placed on both sides of the dam. The area of the reservoir is 0.178 km^2 , which is rather small compared with other dams of the same size. This is due to the very narrow shape of the valley and to the steep gradient of the stream (as high as 1 on 40). The dashed line on Figure III of Plate 9 of this report and Figure 4 of Reference 9 shows the proposed increase of the dam by 9.35 m in height and 4.1 million m^3 capacity.

The bottom outlet of the dam is a concrete conduit. On the downstream side of the core, the outlet has two pipes, respectively 1.100 m and 0.600 m in diameter. At the control, discharge capacity of bottom outlets is $15.0 \text{ m}^3/\text{sec}$. For emergency closure of the outlets, there are two butterfly valves located at the point where the conduit passes through the core wall. In the event of breaking of the pipe, these valves close automatically by means of a float.

A small turbine 4.0-37.2 HP capacity, according to the head, utilizing the smaller bottom outlet is installed in the valve house. The generated power is used for illumination and heating of the buildings of the dam site. A small amount of the utilized water is released into Kali River.

The high water release structure consists of a spillway tower, and a flume, which passes through the dam by means of a tunnel and a transition. The structure is designed for $43.5 \text{ m}^3/\text{sec}$ corresponding to $1.50 \text{ m}^3/\text{sec}/\text{cm}^2$. Design was established and tested by model experiments made at the Technical University at Karlsruhe. The round spillway tower was selected in order to facilitate proposed future increase of the height of the dam. At the assumed highest high water, the overflow depth is 0.74 m. There is a free board of 2.26 m available. (See Plate 9 of the report).

9. THE KALL TUNNEL (References 9, 10, and 15).

The tunnel is reinforced by an inside concrete facing approximately 0.30 m thick to withstand the mountain pressure. In some places, this concrete is reinforced with steel. In some places, the floor also has to be reinforced against upward pressure. These reinforcements extend for approximately $1/3$ of the length of the tunnel. The inside of the tunnel was provided by a "torcret" facing for protection against water seepage. Approximately 1.0 million m^3 of seepage water is accumulated in the tunnel in a year.

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The entrance to the Kall tunnel is located on the left slope of the valley approximately 500 m upstream from the Kall Dam. This location was selected in order to avoid a long service bridge. The spillway tower has three outlet openings at high elevations in order to tap the layers of pure water.

Flow through the tunnel is regulated by a segment gate. A stop-log emergency closure is located outside the entrance. On opening all three inlets at full pool, the flow of water through the tunnel into Dreilaugbach Reservoir amounts to 8.0 m³/sec.

10. RECONSTRUCTION OF WAR DAMAGES (Reference 14).

a. The Rur River valley was the center of a very intensive military operation in the last phase of the World War during the period November 1944-March 1945. The hydraulic installations of the Rur and its tributaries, controlling the water and power supply of the area were the target of Allied military actions, while at the same time they were used extensively by German Armed Forces for defense.

The Dreilaugbach and Kall Dams were captured by American Army in practically intact conditions during the period September-November 1944, and immediately placed in operation, as a source of drinking water supply for the Aachen area.

All other dams (Schwanenau, including the Paulushof auxiliary dam, Urft, Heimbach and Obermaubach) were seriously damaged, partly by Allied air raids, but most severely by the retreating Germans.

b. Schwanenau dam was, on several occasions, subjected to heavy Allied bombing. The resulting craters were 20-40 m in diameter, but only few meters in depth, which was insufficient to endanger the structural safety of the dam.

In February 1945, shortly before surrendering the dam, the Germans blasted its main operating installations. One of the 2.0 m diameter bottom outlet pipe lines was blasted. This action caused the ring-valves and butterfly valves of both bottom outlets to be destroyed and swept away. Also the emergency gate at the upstream outlet entrance of the reservoir was destroyed by explosion.

c. The Allied air raids caused 5 breaches 1.3-3.50 m deep, on the crest of the Urft Dam. As the dam was filled to capacity at this time, a great amount of water flowed over, creating a flood wave. In addition, the air raids destroyed the upper part (20-24 m high) of the control tower and outlet conduit as well as the bottom outlet control mechanism. The lower part

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of these outlet conduits, on the reservoir side of the dam, was not affected by the bombing because of protection afforded by the earth fill on top of the conduit.

Upon their retreat, the German Armed Forces blasted the main valve of the 1.5 m diameter pressure pipe above the powerhouse near the surge tank.

d. The Obermaubach control structure was also blasted by the Germans, and the operating flap structure was put out of commission.

e. As the result of these destructions caused by the German Armed Forces, the reservoirs of both Schrammsau and Urft Dams were emptied, creating flooding condition for weeks along the entire Rur River valley, destroying practically all installations which were not already destroyed by bombing or by blasting by the retreating Germans.

The reconstruction of all hydraulic installations started immediately after the occupation of the territory by Allied Forces in the latter part of 1945.

The present intention of the planners is to reconstruct all the above-mentioned hydraulic structures and pertinent installations into original operating conditions and improve them where possible.

Neither Schrammsau nor Urft Dams were substantially endangered in their structural stability or impermeability, which facts were checked by subsequent tests.

f. Schrammsau Dam — reconstruction 1945-1949.

Prior to 1949, only the emergency closing valve of 0.500 m diameter, flanged with the 2.00 m diameter outlet pipe, provided for controlled discharge out of the dam. The maximum capacity of this emergency control was 9.0 m³/sec compared with the 80 m³/sec capacity of the original outlet valves. Utilizing this emergency closure, the dam was filled in 1946 during the high water period up to 92.0×10^6 m³.

This 1949 article (Reference 14), mentions the reconstruction of power generation to normal operating conditions. No mention is made concerning the reconstruction of other operating mechanism of the dam; however, it may be assumed that since 1949, progress was made towards normal operating conditions with new installed mechanisms.

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g. Urft Dam — reconstruction 1945-1949.

The wall of the dam which was hardly damaged by bombing and blasting was completely restored. Also the outlet operating towers were rebuilt in concrete.

The valve in the 1.5 m pressure pipe line, which was blasted by the Germans, was replaced by a valve of an improved construction but of the same size and capacity. Also the pressure tunnel was repaired. The velocity in the tunnel is 3-4 m/sec. In the pipe line, it is 8.0 m/sec. Consequently, it appears probable that the Urft Dam is now in normal operating condition.

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EXHIBIT C

EXCERPTS

FROM

"ENGINEER OPERATIONS BY THE (U. S.) VII CORPS

IN THE EUROPEAN THEATRE

VOLUME VI

THE ROER RIVER CROSSINGS AND

ADVANCE TO THE RHINE"

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THE CROSSINGS OF THE ROER RIVER
AND
THE ADVANCE TO THE RHINE

THE TACTICAL SITUATION PRIOR TO THE CROSSING

1. 12 September 1944 VII Corps entered Germany near Aachen. During the next three months the Corps completed the destruction of the Siegfried Line in its zone, captured Aachen, cleared the Germans from the difficult Hurtgen Forest, and reached the line of the Roer River between Obermaubach and Krauthausen on 19 December.
2. The German breakthrough which commenced on 16 December in the Ardennes resulted in the shifting of VII Corps and its Corps Troops initially to the area between Huy and Dinant in Belgium. Following the reduction of the breakthrough, the Corps was withdrawn from action on 25 January 1945 and on 5 February assumed the zone on the Roer River shown on map, Appendix No. 1.*
3. The area to the east of the Roer offered good defensive possibilities. The town of Duren and numerous built up communities lay within small arms range of the river. Field fortifications had been under construction for four months. The entire area was heavily sown with both antipersonnel and antitank mines. Heavy concentrations of artillery had been moved into the area.

THE TACTICAL PLAN FOR THE CROSSING

4. The tactical plan for the crossing of the Roer River provided for the attack by Ninth Army to cross the Roer and advance to the Rhine in the area opposite Dusseldorf. First Army, on the right of Ninth Army, would advance and cover the right flank of Ninth Army. It was felt necessary that the storage reservoirs on the Roer River system be seized prior to the beginning of the operation to prevent their use by the German army to flood the river and interrupt the crossing. The XVIII Airborne Corps and later the III Corps on the right of VII Corps was given the mission of seizing the Schwammenauel Dam while V Corps captured the Urft Dam. The capture of the former was a difficult tactical operation and while its capture was effected finally on 7 February, the Germans had opened the outlets from both dams and destroyed the operating mechanisms. The river rose rapidly and inundated areas along its low lying banks.
5. Due to the tactical situation, no accurate stream velocity measurements could be obtained; estimates placed it as high as 10-12 miles per hour. Reconnaissance established the fact that a crossing in the swift, turbulent stream with the standard equipment available would be extremely hazardous, and the operation was delayed until the velocity had moderated.

*Omitted

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6. VII Corps, on the immediate right of Ninth Army, planned to cross the Roer with two Divisions at the same hour as Ninth Army. The 104th Infantry Division, on the left of the Corps, planned to cross two regiments abreast, each regiment crossing two battalions abreast, each battalion with two companies abreast. The 8th Infantry Division, on the right, followed the same general plan except that the extreme right battalion was to be crossed 40 minutes prior to H-Hour which was set for 0330 on 23 February. Division boundaries are shown on 1:50,000 map, Appendix No. 1.*

7. The plan of VII Corps provided also for the early passage of the 3d Armored Division across the river to break out on the front of the 104th Infantry Division, seize a crossing of the Erft River, and cover the flank of the advancing Ninth Army to the Rhine. This made the early construction of Class 40 bridges across the Roer a matter of urgency.

8. III Corps, on the right, was to cross the river on 25 February, two days after VII Corps. This factor was responsible to some degree for the difficulty of the crossing in the 8th Division sector. Terrain to the right of the 8th Division on the east side of the Roer provided excellent observation of the river in the entire 8th Division sector, and it was not until after the 25th when the 1st Division moved east of the river that accurately adjusted artillery fire was finally lifted from the bridge sites in the 8th Division sector.

THE ROER RIVER AS A MILITARY BARRIER.

9. The Roer River rises in the Eifel Region south of Monschau and flows in a northeasterly direction to Kreuzau where it leaves the foothills and enters the Rhine plain. Here it turns north, flows past Duren and Julich and joins the Moselle River at Remond.

10. The river has a steep gradient, approximately 14' per mile until it reaches the area between Duren and Julich. To control the velocity and to provide water for manufacturing processes, low check dams had been installed in the river approximately every kilometer. During normal water stages the velocity of the river is moderate and the width within VII Corps sector approximately 125 to 150 feet. The river was fordable by foot troops at many points.

11. Two main reservoirs had been constructed by the Germans on the river as shown on map, Appendix No. 1.* The first and older of the two, the Urft Dam, has a storage capacity of 1,600 million cubic feet. This is a large concrete and masonry dam with a normal discharge through conduits to a power station at Hainbach. Between 1935 and 1940 the Schmausenauel Dam, a large earth structure capable of impounding 3,500 million cubic feet of water was constructed. The discharge from this reservoir passed through a power station located immediately below the dam.

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12. Prior to the seizing of the Roer River line, attempts had been made by the Allied Air Forces to destroy these dams by aerial bombardment without satisfactory results. The bombardment did result in a reduction of the level in both reservoirs by the Germans. As the drive to capture the reservoirs was about to succeed, the outlet gates were opened to the obviously pre-determined amount required to obtain a maximum velocity in the stream. The river level rose 7-10 feet initially, then dropped about 1-1/2 feet and remained constant. The effect of the check dams was eliminated by the increased depth, and velocities rose to 12 miles per hour in a few places in the Corps zone. The width did not increase to any great amount, but for the most part it rose over the low banks and inundated areas on both sides of the river. The inundations were wider in the Ninth Army zone. Photos Nos. 1, 2, 3, and 4 were taken during the period of flood stage, and show the extent of flooding.

13. The river reached a "stable maximum" height about 9 February; thereafter the elevation and velocities remained constant for a period of ten days. Data on velocities and a description of the operation of boats on the river are contained in Appendix No. 2, "Use of Assault Boats on the Roer River in Flood Stage." As the level in the Schwemmenau Dam approached zero, the river level and velocity began to decrease rapidly. Based upon engineer estimates, the assault crossing time was established at 0330 on 23 February. Velocities were still high, being over 8 miles per hour in the southern part of the Corps zone.

14. Essentially, the Roer River was an excellent switch position for the Siegfried Line. The south flank of the Roer rested in the extremely difficult forested terrain east of Minschau. The two reservoirs provided excellent barriers for long distances. The arrangement for controlled flooding provided a means of securing the river line for a limited period of time in view of the fact that no river crossing equipment available to our army will negotiate currents of 10-12 miles per hour. The German Army secured a delay of more than two weeks in our offensive to seize the Rhine. Appendix No. 3, "Study of Possible Flooding of the Roer River," contains a detailed analysis of the river control and the capabilities of the river as a barrier. This study was prepared in December 1944, and the capability outlined in paragraph 6 was put into effect. First Army Engineer estimates placed the actual discharge at 3500 to 4000 feet per second.

PREPARATORY WORK FOR THE CROSSING

Paragraphs 15-19 (omitted)

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THE ASSAULT CROSSING BY THE DIVISIONS

20. The 104th Division crossed with two regiments abreast, two battalions abreast within each regimental zone. The left regiment crossed two rifle companies of one battalion and three of another in the assault. The right regiment crossed two companies of each of the two battalions abreast. A total of nine rifle companies were in the assault wave.

21. The division engineer placed one platoon of engineers with 16 assault boats in support of each rifle company, and reinforced the platoons to a strength permitting the use of three engineers per boat load of 10 infantrymen. One hundred forty-four boats were employed initially, with 60 in reserve at three different locations. Because of previous intensive training of the engineers, every boat in six companies reached the far shore safely and 15 boats landed safely in the seventh company. In the crossing of the eighth company, four enemy machine guns were adjusted on the site, and only four boats crossed safely. The balance of the force withdrew and crossed at the site of a previous successful crossing. The ninth company came under heavy mortar and artillery fire and successfully crossed only six boats, lost seven in the river, and had three damaged prior to entering the water.

22. Casualties were sustained by the eng. as at all except one site; they ranged from a maximum of ten at one crossing, the result of small arms fire to one at an unopposed site. Casualties totaled 8 killed, 145 wounded, and 1 missing out of approximately 400 engineers actively engaged in the crossing sites; a rate of 38 per cent. See Appendix No. 4. *

23. Of the 204 assault boats available, 187 were used; 28 of these were destroyed and 108 were damaged. Due to the stream velocity, only 8 boats could be returned to the near shore from the original 144 used in the assault crossings; three engineer soldiers could not control the boats on the return trip.

24. It has been planned to construct footbridges to cross the reserve infantry companies, but the stream velocity would not permit. In lieu of footbridges, cable ferries were put into operation by five of the nine engineer platoons, using assault boats from reserves. Two platoons followed the infantry and gapped a minefield on the far bank.

25. Storm boats, and double assault boats powered with 22 HP outboard motors, although available, were not used in the 104th Division assault crossing.

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26. The crossing of the 8th Division was similar in all respects to that of the 104th with the added handicap of an exposed right flank from which observation of the river within the Division zone was possible. Only two engineer companies were used for the assault boat crossings; the third company was assigned the construction of footbridges. One regiment was crossed in rowed half boats, the other in powered double assault boats supplemented by rowed boats. Casualties in both men and equipment were higher in this crossing than in the 104th Division. The rowed half boats could not be returned, the footbridge construction was impossible, and artillery fire damaged many of the boats before they could be launched.

CONSTRUCTION OF BRIDGES BY CORPS ENGINEERS

27. To support the operation of the Corps, the Corps Engineers were assigned the mission of constructing all of the bridges, leaving Division Engineers free to handle the assault crossing of the Infantry. Five bridges were planned for each Division Zone. Two of these were to be Infantry Support Bridges, Class 9, one in each regimental zone. One of the Treadway bridges was to be constructed with the conversion set to permit the passage of the new T-26 tank. Two sites were available in the entire Corps zone where Bailey Bridges could be constructed without technical difficulty, and it was planned to build at these two sites as rapidly as the tactical situation would permit.

28. Bridge construction was ordered to commence as soon as possible after the crossing of the infantry. On all previous river crossing operations of VII Corps, bridge construction had been started immediately after the assault infantry had secured a lodgment on the far bank, and the bridges had been finished within a few hours after the initial crossing. In the Roer crossing, the observation afforded the enemy by the buildings in Duren and from the high ground south of the 8th Division zone enabled him to keep the bridge sites under observed artillery fire for 24 to 56 hours and contributed to the relatively high number of casualties sustained.

29. Smoke to screen the operation had been requested. Smoke generators were not made available, but a few trained non-commissioned officers from a Chemical Smoke Generating Company were secured, and a small supply of smoke pots was moved up. Control of the use of smoke was delegated to Division Commanders, who decided against its use during the early hours of 23 February. When the intense artillery fire continued during the day, authority to use smoke in one Division zone was given, but it proved to be quite ineffective. The equipment and men had been committed to sites which had been observed and upon which enemy artillery fire had been registered.

30. During the night of 24-25 February, and thereafter, the water level in the river fell rapidly following the emptying of the Schwanenauel Dam. This added to the technical difficulties of construction of the floating bridges at sites 7, 9, and 10.

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DETAILS OF EACH CROSSING

Paragraphs 31-45 (omitted)

APPENDIX 1 (omitted)

MAP SHOWING ROER CROSSING AREAS

APPENDIX 2

USE OF ASSAULT BOATS ON ROER RIVER IN FLOOD STAGE

During the night of 10-11 of February, the 329th Engineer Combat Battalion sent two patrols to the Roer River to attempt to cross in assault boats. The purpose of the patrol was to determine if an assault boat could be handled in the river at flood stage by fully equipped Infantry troops who had little or no training in assault boat crossings and to also determine if it were feasible to put a cable across the river to provide anchorage for a trail ferry. The results of the two patrols are as follows:

PATROL NO. 1

Two officers and ten men took an M-2 assault boat to the Roer River at the following coordinate (10054680), with the purpose of taking a light cable across the river. Upon reaching the river bank, the two officers decided that the water was too swift to do any more than attempt to paddle across the river without dragging the 1/4" cable that they had brought to the site. They loaded the boat with two officers and six enlisted men each equipped with a paddle. None of the men carried any equipment except for a carbine, which was on the bottom of the boat, and a rubber self-inflating life belt. All men were well trained in assault boat work and had worked together with the equipment for two years.

The current at the launching point was estimated at ten miles per hour and very turbulent due to the speed of the water, rather than to obstacles on the river bed. It also seemed to flow from the near to the far bank. After loading the boat, they headed upstream and paddled as rapidly as possible. When they reached the main channel, they lost control of the boat, but due to the current were swept to the far bank into relatively calm water. From there they paddled upstream and started rapidly back. Almost immediately after they started back, the men lost control and the boat was swept over a weir, which was approximately 150 yards downstream from the initial launching point. The boat filled with water until about four inches of the gunsholes were showing. As they went over the weir, one of the officers told the men to inflate their life belts. The current swept the boat with all the men in it near some bushes on the near bank. The men grabbed the bushes to stop the boat, but the current got into the rear of the boat and turned it end over end.

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Lt. Field and three of the men held onto the bushes and pulled themselves ashore. One man was found 150 yards downstream, conscious, but unable to breathe due to the shock of the cold water. Another man was found 300 yards downstream in the same condition. A search was made by the other men in the boat and by the four men on the bank, but they were unable to locate Lt. Brainer or Pvt. Brannison.

Conclusions drawn by Patrol Leader:

1. A boatload of inexperienced Infantry troops with full load would have very little chance of crossing the river in assault boats at its present stage.
2. If a boat is tipped, the men would have a very difficult time reaching shore due to the cold and turbulent water, even if wearing life belts.
3. A 5/8" cable well anchored would probably hold an assault boat ferry, but great care would have to be taken or the boat would swamp due to the rapid current.
4. Obstacles in the water near the shores, such as barbed wire, stumps, etc., would prohibit the use of steam boats in this area.
5. An assault boat will be approximately 250 yards downstream from its starting point when it reaches the far bank.

PATROL NO. 2

Lt. McKain, with several men from Company C, attempted an assault boat crossing of the Roor River at (086510). The river at this point was four hundred yards wide and is divided into three channels. The first is about three feet deep, with shallow water over a bar that is about 100 yards from the near bank. The second channel is approximately four feet deep. The sand bar between this second channel and the main stream offers an obstacle to an assault boat.

Lt. McKain loaded four Engineer and eight Infantry soldiers, about half of whom were carrying rifles, into the boat; tied a rope to the gunwale and the men started paddling with the boat headed upstream. At the first bar, the men had drifted 200 feet downstream. At this point, half of the men unloaded and pushed the boat over the bar. They then climbed in and paddled to the middle of the main channel. They were being swept downstream so rapidly that the men in the boat pulled the boat back to the starting point. Ten men holding the rope on the near shore assisted in pulling the boat back with little difficulty.

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Conclusions drawn by Patrol Leaders:

1. An assault crossing could be made at this point by Infantry troops.
2. The boat would have to start 200 to 300 yards upstream from the proposed landing site.
3. A rope tied to an assault boat makes a drag, at least equal to the drag of the boat.
4. Men are not able to wade in 3 feet of water on the secondary channels and keep their feet.

PATROL NO. 3

At 200030A February, a crossing of the Roar was effected by a 6-man Engineer patrol from Company C, 329th Engineer Combat Battalion.

The mission of the patrol was to reconnoiter the river at its present stage and also to transport a German PW who volunteered to obtain information for our forces of enemy disposition and identification in Duren and Birkesdorf.

The crossing was made in the vicinity of Heven at coordinate (P093489) using an M-2 Assault Boat. It was originally planned to cross at 2200 but due to the extremely bright moonlight, the crossing was postponed until 0030 when visibility decreased. However, visibility was excellent up to 250 feet.

The width of the river at the crossing site was estimated at 250 feet. This is a decrease of 50 feet from previous reconnaissance reports of 12-13 February. The velocity of the current was estimated at 7-8 MPH. All patrol members agreed that the current was not as swift as recorded 12-14 February.

The boat was launched in shallow water 30 feet from the near shore. With 5 men paddling and 2 passengers, the crew experienced no difficulty in crossing and the drift was only 10 yards downstream. On the return, with 5 paddlers and 1 passenger, the drift was 40 yards downstream. This discrepancy in driftage was explained by the fact that the boat was purposely allowed to drift over a series of riffles in the main channel in order to determine the amount of drift if the boat were caught in the current. The boat (loaded) would not cross a gravel rise on the far side which was some 60 feet from the far shore. This gravel rise is the original east bank of the river. The PW debarked here and was observed wading in water of 2 feet in depth.

All observations indicate that the water is draining. However, the ground is soft and wet, and there is standing water on the far shore.

No hostile enemy action was encountered. The crew experienced no difficulty in crossing. No life belts were worn. The crew was armed with carbines. Crossing time was estimated at 6 minutes.

APPENDIX 3

STUDY OF POSSIBLE FLOODING OF THE ROER RIVER

1. The Roer River rises in the Eifel Mountains south of Monschau. It flows in a northeasterly direction through mountains to Kreuzau, where it enters the rolling Rhine Plain. Here it turns north and flows by Duren; thence northwest by Julich and empties into the Meuse River at Roermond.

2. There are two main storage dams on the upper reaches of the river - the Urft Dam (FO723) with 1,600 million cu. ft. capacity and the Schmidt (Roer) Dam (FO827) with 3,500 million cu. ft. capacity. In addition there are three regulating dams - one between the Schmidt and the Urft Dams (FO46240) and two downstream from the Schmidt Dam at (F111262) and (FO95360).

3. The normal discharge of the Schmidt Dam is 320 cu. ft. per second.

4. Independent of the Roer River Dam system is the Kall Dam (FO230) on the Kall River, a tributary of the Roer. This dam has a capacity of 74 million cu. ft. and has been secured by the V Corps.

5. To present a military obstacle the water supply impounded by the aforementioned dams can be used to raise the level of the Roer River so high that it will overflow its banks, wash out existing bridges and cause damage throughout the Roer River Valley.

6. Since the Roer River has a steep gradient (approximately 14 feet per mile) and at high water a great velocity, it is estimated that a continuous water obstacle from the Roer Dam to the Meuse River could be produced with a discharge of 3,500 cu. ft. per second from the dams mentioned. The total volume of the basins named amounts to about 5,600 million cu. ft. From the latest available photo coverage it appears that the reservoirs are about two-thirds full. Thus, a flow of 3,500 cu. ft. per second would last about 12 days. The estimated depth of the flood produced by this discharge would be 6-1/2 ft. at Zerkall (FO93334), 6 feet at Duren (F109453), 5 feet at Julich (FO27589).

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7. The flood gates of the equalizing basins at Heimbach (F111262) and Obermaubach (F090360) can be opened suddenly to produce a short but high flood wave estimated at 15,000 cu. ft./sec, after complete filling of the basins. This wave can be considerably increased in volume and velocity if the level of the Schmidt Dam reservoir is above the spillway and the opening of the spillway gates is synchronized with the successive opening of the flood gates at the Heimbach and Obermaubach dams. Such a wave would probably not last more than eight hours but it would inundate the Roor Valley to an estimated height of fifteen feet above the normal stream level. This level could be raised further in the Duren area by the erection of barriers at the openings in the railroad and highway fills which extend across the river valley. It is estimated that about 30% of the town of Duren could be flooded in such a manner.

8. Captured German documents dated 3 April 1944 reveal that the maximum water contents of the Urft and Schmidt reservoirs have been limited to 3,885 million cu. ft., which is 1,715 million cu. ft. less than actual capacity. The proposed distribution is 2,330 million cu. ft. in the Schmidt reservoir and 1,585 million cu. ft. in the Urft Dam reservoir. This distribution would allow the contents of the Urft Dam reservoir to be caught and retained in the Schmidt Dam reservoir without undue strain on the Schmidt Dam, in case the Urft Dam, which has slender concrete walls, were blown (witness the case of the Mosine and Eder Dams).

9. The Schmidt Dam is of mass earth fill construction and does not lend itself to easy destruction by either blasting or bombing. The Urft and Schmidt Dams have been bombed by RAF and AAF several times without results, although numerous hits have been made.

10. Although it is not considered probable, it is possible that the Schmidt Dam will be destroyed by explosives. Attached is overlay showing elevations 5, 10, and 15 meters, respectively, above the stream bed of the Roor River. As a precautionary measure it is recommended that large bodies of troops and heavy equipment be kept above 10-meter line south of the Autobahn Highway; similarly that large bodies of troops and heavy equipment be kept above the 5-meter line north of this highway.

Incl:

Overlay (In 2 sheets) - Withdrawn from Report (i.e. from original VII Corps Report)

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APPENDIX 4 (omitted)

CASUALTIES

APPENDIX 5 (omitted)

SUMMARY OF EQUIPMENT

APPENDIX 6 (omitted)

TABULATION OF STREAM CROSSING DATA

APPENDIX 7 (omitted)

MAP SHOWING ROAD NET AND ROER RIVER BRIDGE

APPENDIX 8 (omitted)

PHOTOS OF THE ROER CROSSINGS

APPENDIX 9 (omitted)

TABULATION OF STREAM CROSSING DATA

APPENDIX 10 (omitted)

PHOTOGRAPHS OF ERFT BRIDGES